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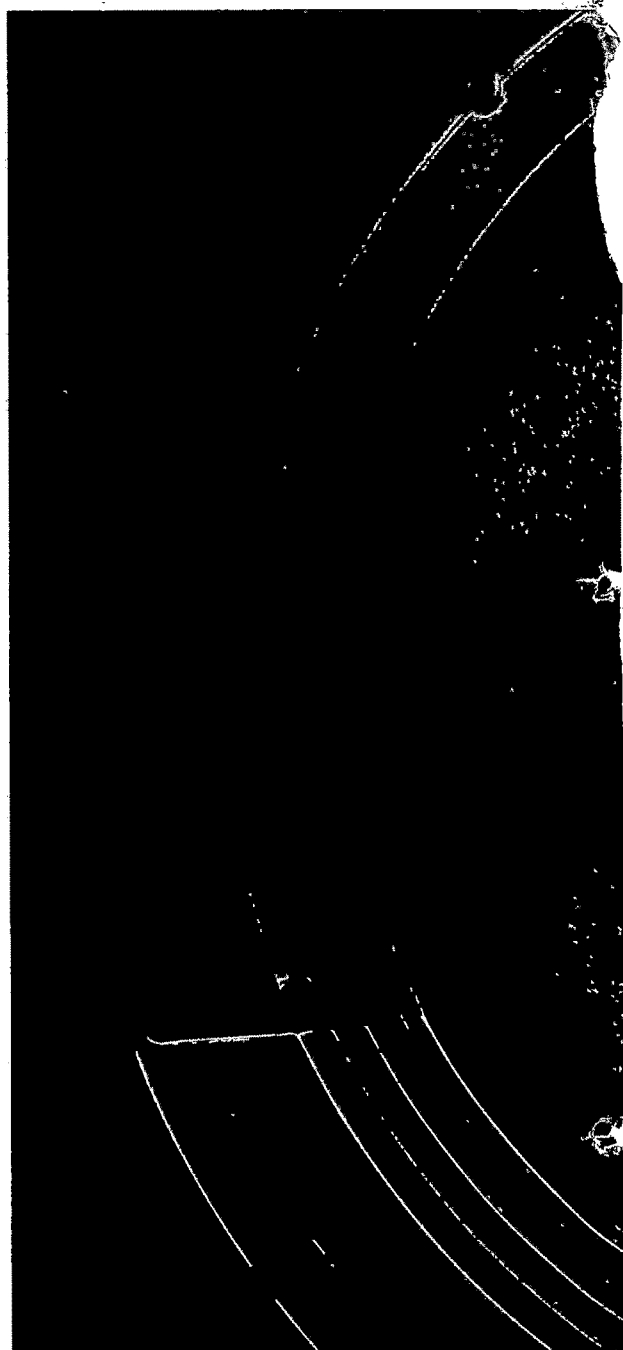
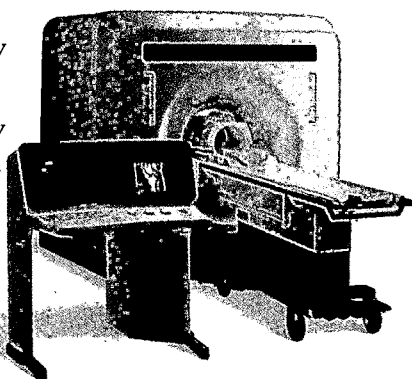
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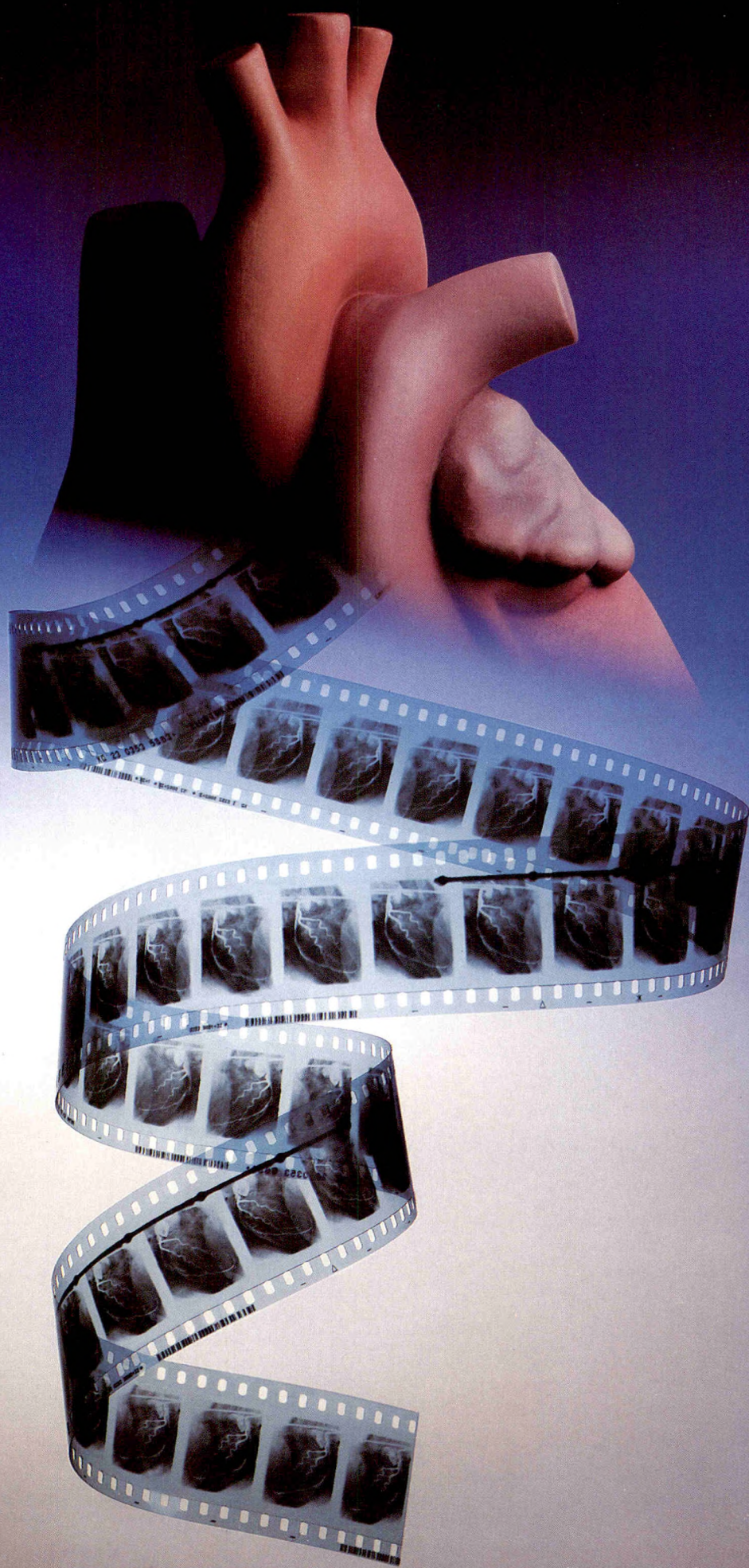
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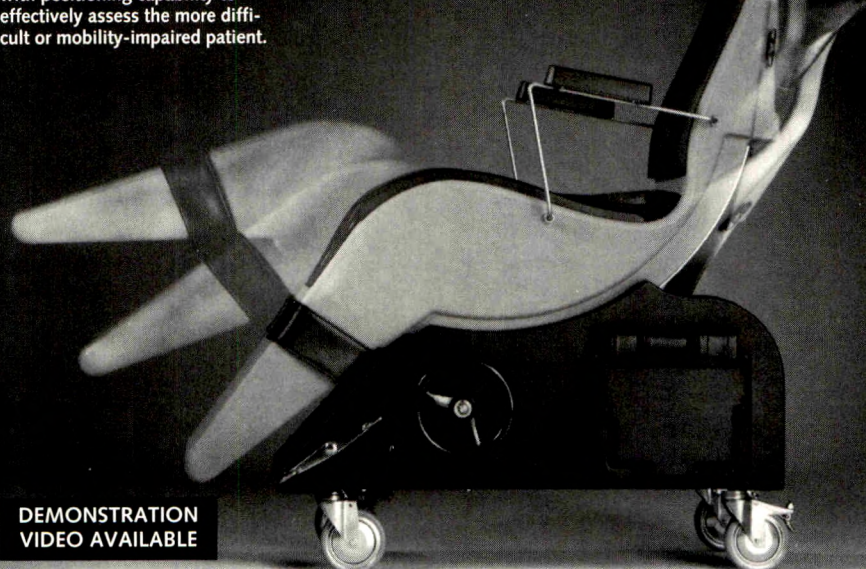


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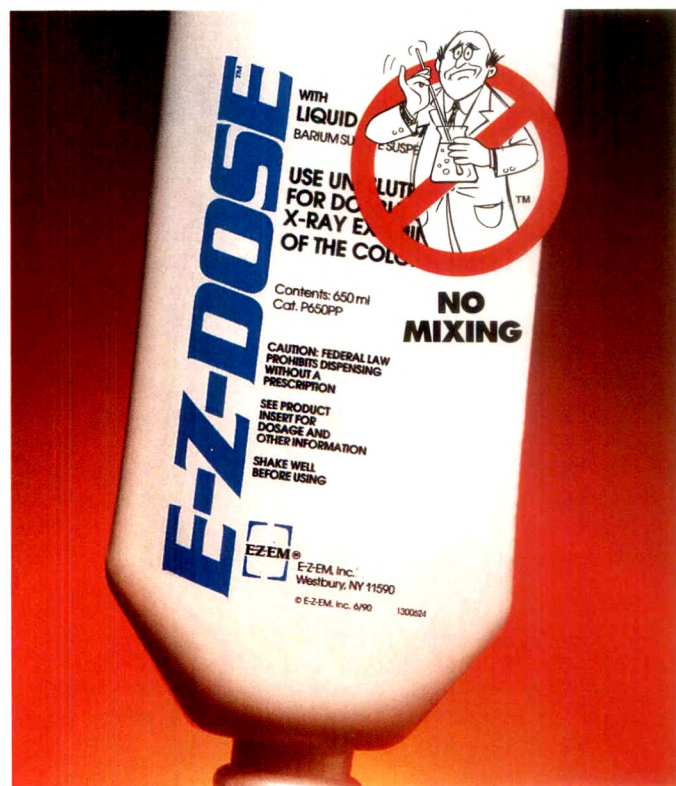


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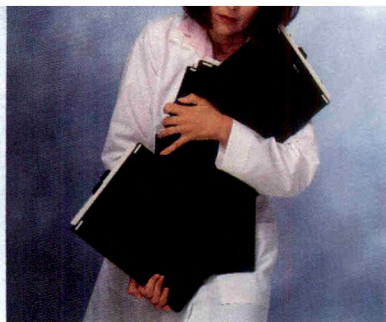
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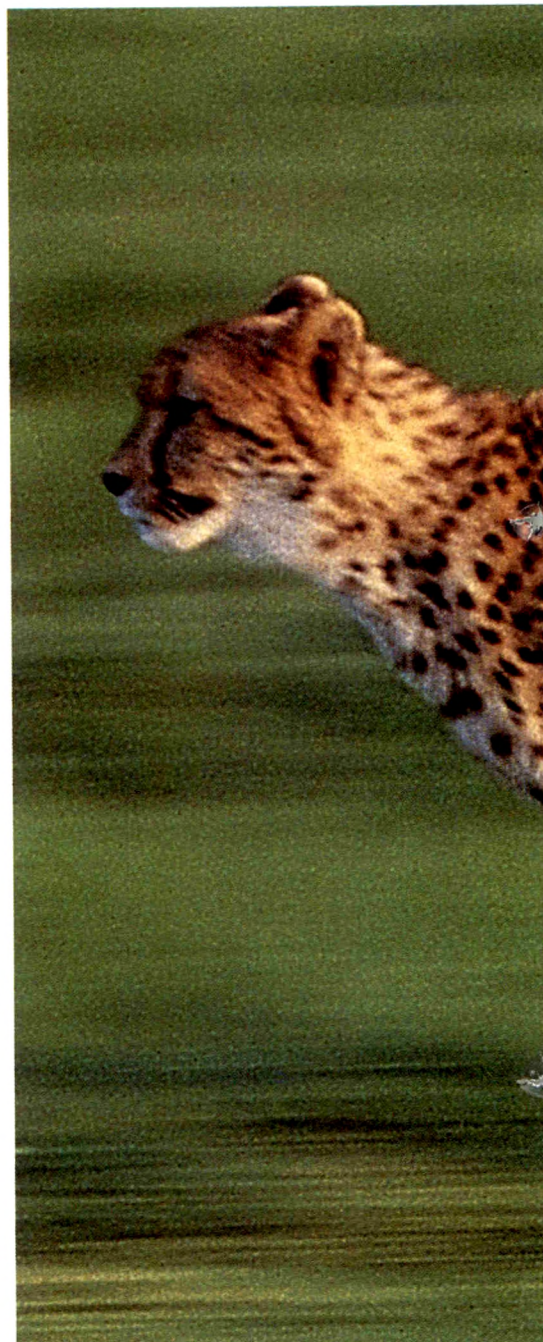
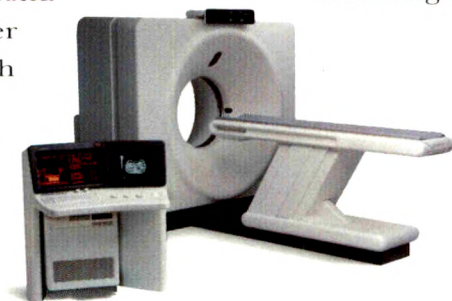
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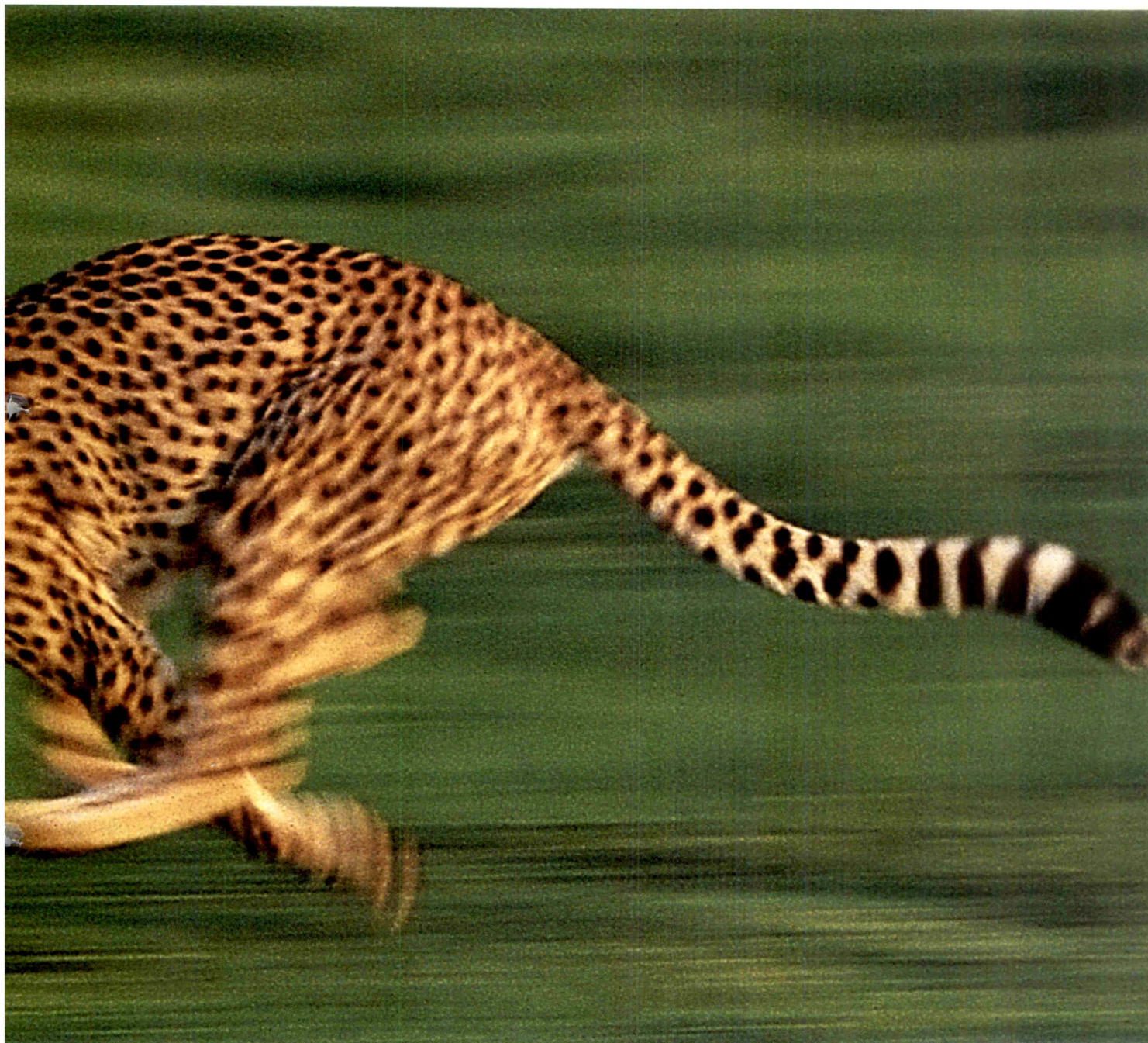
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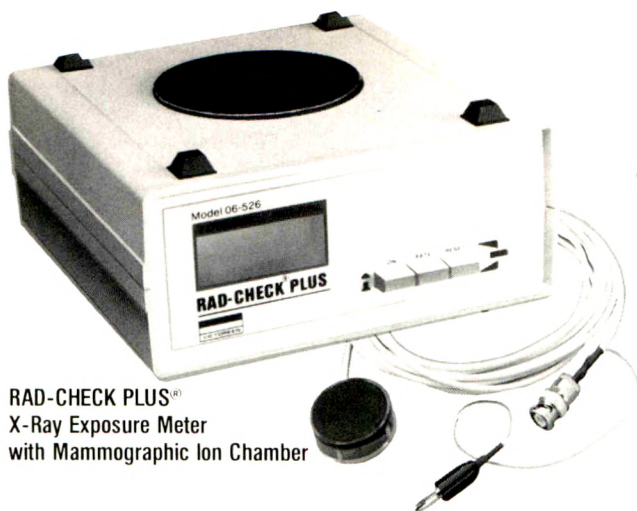
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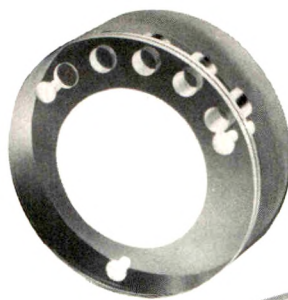




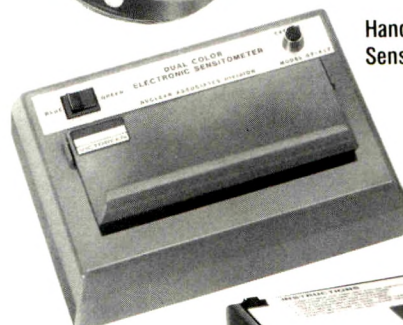
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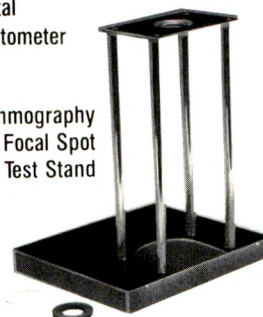
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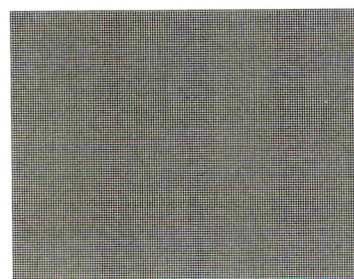


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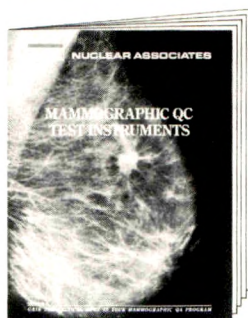


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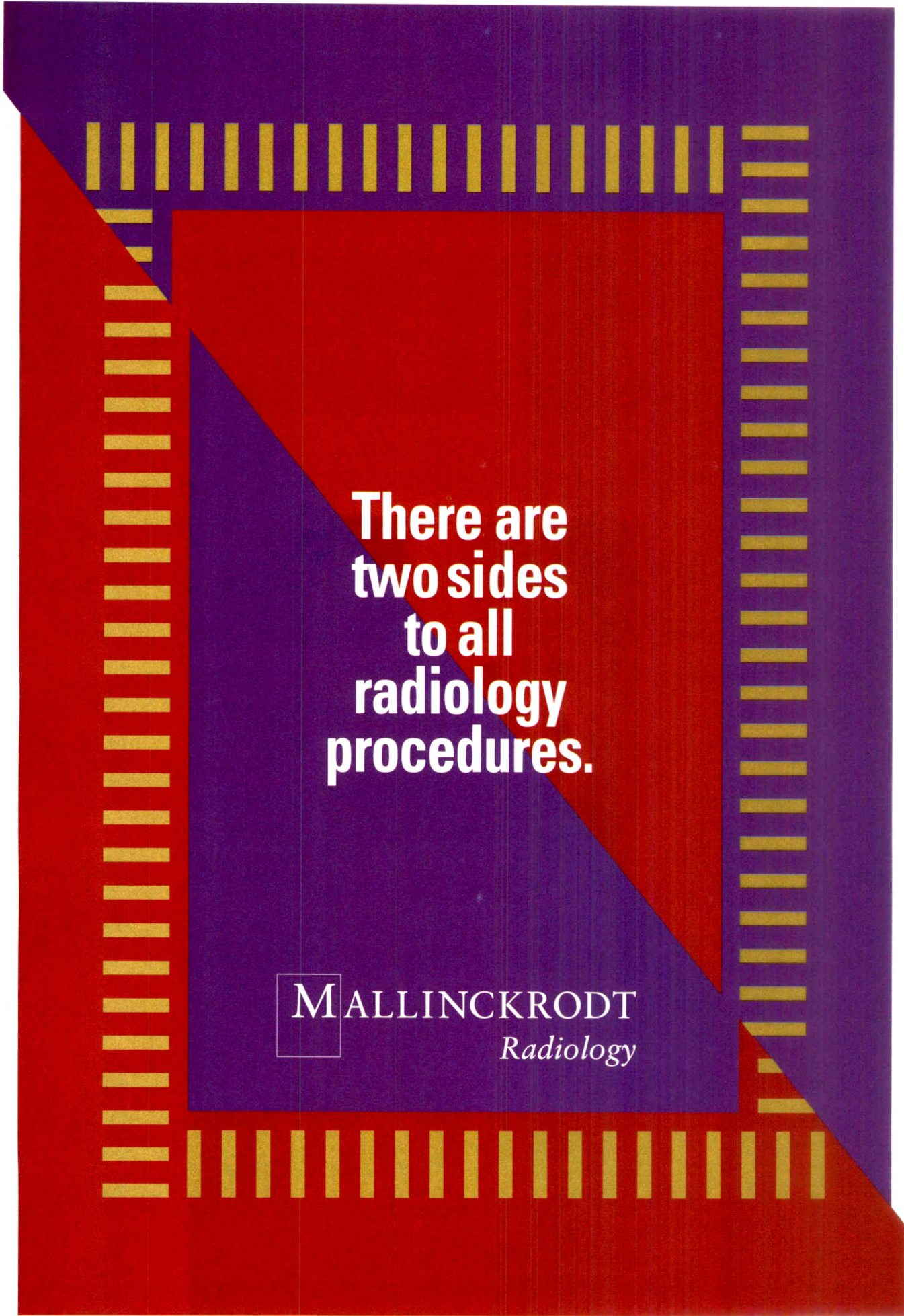
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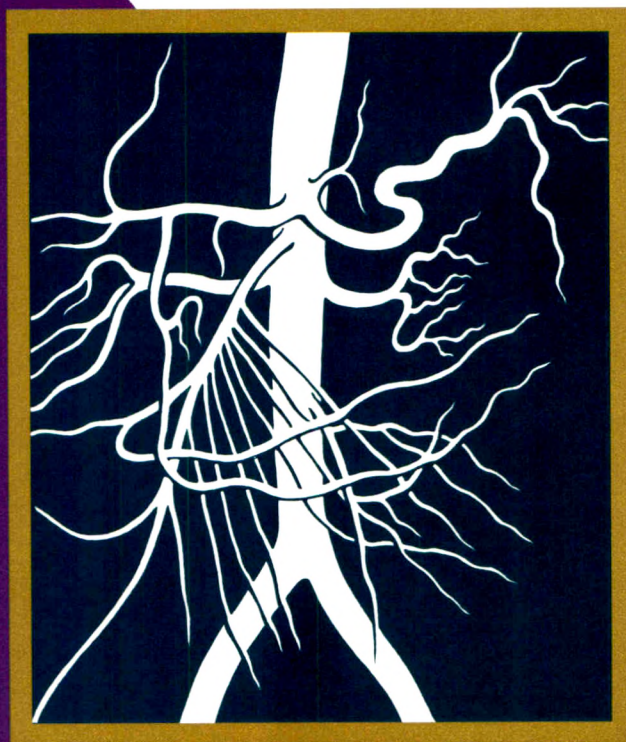
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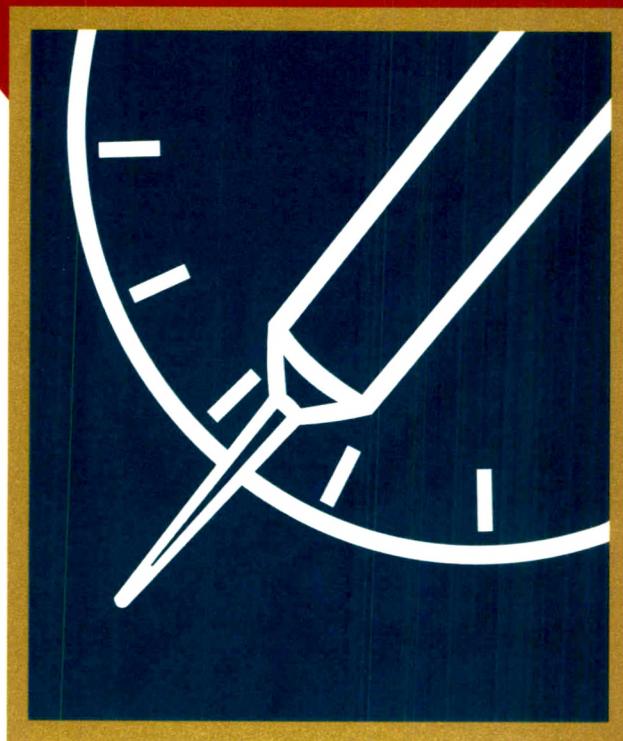
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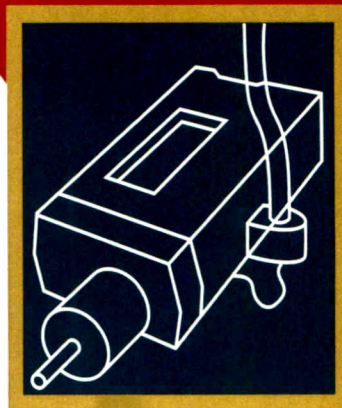
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Review Article

Evaluation of Congenital Heart Disease with MR Imaging: Current and Coming Attractions

Kenneth E. Fellows,¹⁻³ Paul M. Weinberg,¹⁻³ Jeanne M. Baffa,^{2,3} Eric A. Hoffman³

Nearly 10 years of experience in the use of MR imaging for the diagnosis of congenital heart disease has accumulated. Although MR imaging is superior to other techniques in showing certain structures and abnormalities such as small central pulmonary arteries in tetralogy of Fallot, aortic coarctations, and venous connections in heterotaxia syndromes, it remains an ancillary tool to echocardiography and cardiac catheterization. In this review, we examine present limitations and advantages of conventional MR in the evaluation of congenital anomalies of the heart and great vessels and explore future developments that might bring MR imaging into the diagnostic mainstream. Key improvements now in development are ultrafast MR systems for acquisition of multiple real-time MR images (in 30 msec or less) and on-line three-dimensional computer reconstruction of the heart and great vessels. Improved display and understanding of complex anatomy, as well as more extensive functional analysis of hearts before and after surgery, should be the benefits of such developments.

MR imaging has a short history in modern medicine. Although the MR phenomenon has been used for spectroscopic analysis in chemistry and physics since 1946, actual production of clinical images with the technique was not described until 1977 [1]. By 1980, commercially available MR imaging systems were being installed throughout the world, and general clinical use progressed rapidly.

The first reviews of MR imaging in patients with congenital heart disease were published in 1984 [2-4], and they were

mostly enthusiastic reports about the anatomic structures that could be shown. From 1985 to 1990, cine MR imaging of the heart, which uses both gated spin-echo (SE) and gradient-refocused echo (GRE) techniques, was developed, bringing MR imaging of congenital heart disease closer to angiocardiology, the traditional imaging technique used for diagnosis.

Despite this progress and other developments discussed later, outside of a few special centers and exclusive of the imaging of some vascular anomalies, MR imaging has had minor impact on the clinical examination of patients with congenital heart disease. MR imaging currently is a supplementary technique to echocardiography and cardiac catheterization, despite reports of superior sensitivity and specificity for particular defects [3, 5-7]. In this review, we analyze where MR imaging of congenital heart disease is now and where it is likely to go in the near future.

Contemporary MR Imaging in the Detection of Anatomic Abnormalities Caused by Congenital Heart Diseases

ECG-gated SE sequences provide excellent signal-to-noise ratios for static cardiac MR images. Axial, sagittal, coronal, and short- and long-axis T1-weighted views are generally produced by using echo times of 15-30 msec and variable repetition times that depend on the RR interval. Sampling of

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256–512 cardiac cycles is necessary to generate single images or multiple slices with temporal skewing across phases of the RR interval. Sectional thickness is usually 3–5 mm (with a 1-mm gap) for infants and 5–8 mm (with a 2-mm gap) for children and adolescents. Respiratory gating is generally ignored, which probably causes some degradation of the reconstructed images. Software providing respiratory compensation is currently being introduced. Spatial resolution can be enhanced by using the smallest field of view possible and, for infants, by using dedicated pediatric body or head coils.

Experience with MR imaging in anomalies of the heart and great vessels has been derived mostly from ECG-gated SE techniques [5]. The flow void caused by moving blood and the excellent soft-tissue contrast provide good resolution.

Much of the earliest enthusiasm for cardiac MR arose from success in showing mediastinal vessels (Fig. 1), especially the central pulmonary arteries in pulmonary atresia [5] and aortic anomalies such as coarctation (Fig. 2) and vascular rings [3] (Fig. 3). This success has been sustained, and MR imaging is now often used to show both small central pulmonary arteries and abnormalities of the aortic arch [7, 8]. Thin sections of the mediastinum in axial or oblique views usually show the main, right, and left pulmonary arteries in patients with pulmonary atresia and are more reliable than echocardiography [8] in showing the left pulmonary artery in older children and adults. The size of the vessels can be determined, and follow-up examinations can be used to accurately monitor their growth in response to shunts or other surgical procedures [9]. Stenoses in the proximal segments of the right and left pulmonary arteries can be visualized, but not stenoses distal to the hila [6, 8, 9].

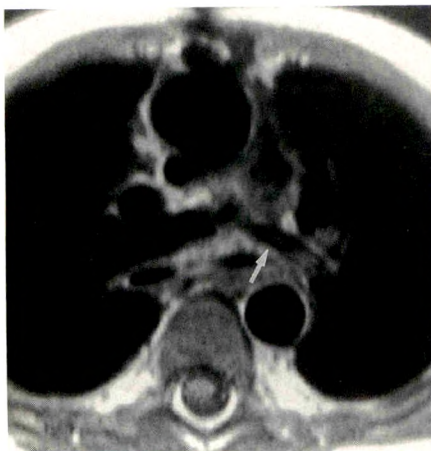
MR imaging has become the favored procedure for showing the anatomy of coarctation (Fig. 2) in children and adolescents [1, 9]; echocardiography is accurate and usually easier in infants. Vascular rings are so well shown on SE sections (with or without ECG gating) that angiography is unnecessary for their visualization [7–9] (Fig. 3). Other anomalies involving the aorta, such as generalized hypoplasia, truncus arteriosus, transposition, supravulvar aortic stenosis, sinus of Valsalva aneurysm, and ductus arteriosus, can be clearly imaged by

using SE sequences [8], but these conditions are usually evaluated by using echocardiography or cardiac catheterization to obtain hemodynamic information and to detect any accompanying anomalies. Marfan syndrome and Turner's syndrome are both complicated by cystic medial necrosis of the ascending aorta [8], and the associated pathologic dilatation is best assessed and monitored with MR imaging [7, 8].

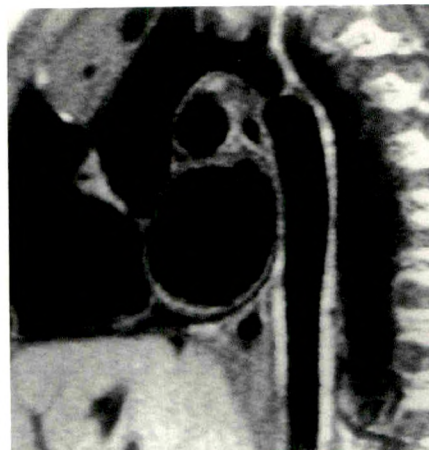
The ability of MR imaging to show myocardial and pericardial masses is well documented [1], although tumors and cysts are infrequently congenital.

Because SE techniques provide clear images of the entire heart, and show thoracoabdominal anatomy, they are valuable in the assessment of congenital heart defects. Their usefulness has been shown with both high- and low-field-strength systems (0.15–1.50 T) [10] and in infants as well as in children and adults [11]. The visceral-atrial situs can be accurately shown [1, 7] because the field of view with MR is large compared with that of echocardiographic and angiographic techniques. Although sonography is superior to MR imaging for detecting abnormalities of the semilunar and atrioventricular valves, MR imaging is better for showing anomalies of systemic and pulmonary venous connections [1, 6, 7, 9] (Fig. 4). Other clinical instances in which MR has been superior to echocardiography and angiography are congenital defects resulting in giant cardiac chambers (such as Ebstein's anomaly) and conotruncal anomalies in which the anatomy is obscured by proximity to the anterior part of the chest, sternal wires, or other surgical deformities [7, 9, 10]. In general, MR is better than echocardiography for assessment of ventricular size [12] and of the postsurgical heart [1, 5, 13, 14].

Cine MR imaging can be produced by using GRE techniques and short echo (5 msec) and repetition (20 msec) times (Fig. 5). Flowing blood has a high signal intensity, and by using a video loop format, up to 32–60 phases of the cardiac cycle can be shown from a 2-min scan. Although cine MR provides less soft-tissue detail than conventional SE MR imaging does, it is now undergoing evaluation for possible contributions to the investigation of morphology in congenital



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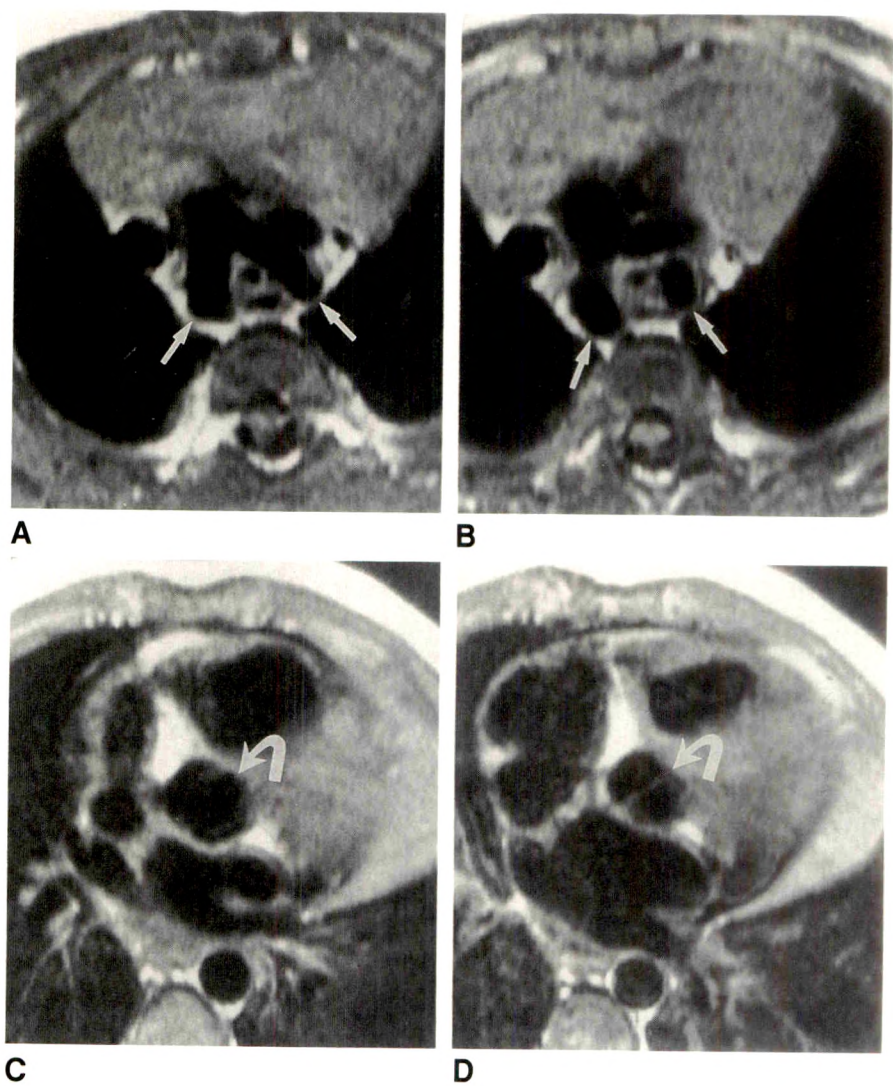


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Fig. 1.—Hypoplastic left-heart syndrome after stage I (Norwood) palliation. SE MR image shows hypoplastic, but patent, left pulmonary artery (arrow).

Fig. 2.—Sagittal SE MR image shows aortic coarctation.

Fig. 3.—A–D, Transverse SE MR images show double aortic arch (straight arrows, A and B) and bicuspid aortic valve (curved arrows) in systole (C) and diastole (D).



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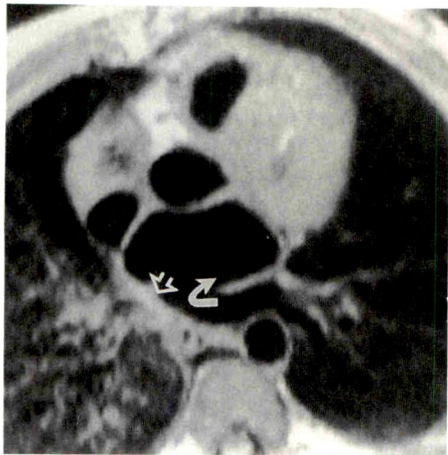


Fig. 4.—Transverse SE MR image in an infant with edema of right lung shows atretic right pulmonary veins (open arrow) and normal connection (solid arrow) of left pulmonary veins to left atrium.

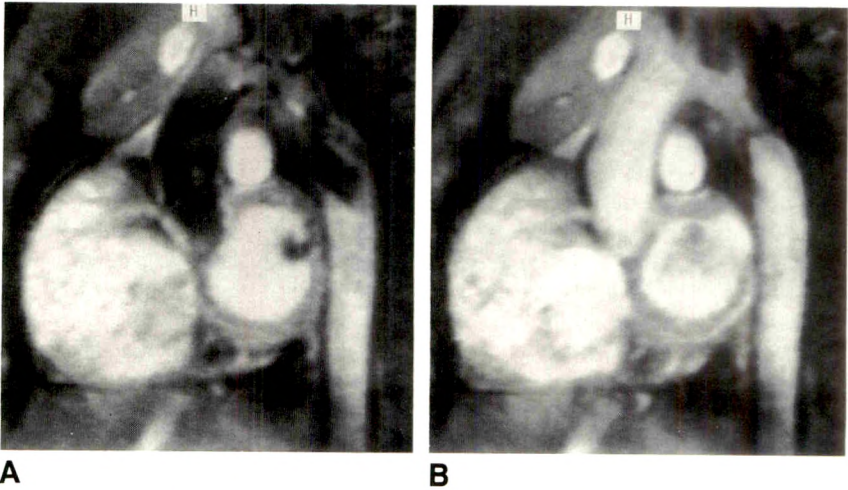


Fig. 5.—A and B, Sagittal GRE MR images in an infant who had valvular aortic stenosis and coarctation. Normal (laminar) flowing blood is usually bright (white). Image obtained during systole (A) shows turbulence above stenotic aortic valve and at coarctation produces "dark blood," which returns to a normal bright character in diastole (B).

heart disease. A study [15] of 91 patients 6 weeks to 14 years old showed that diagnostic imaging was possible 95% of the time and that the technique was most useful for evaluating the right ventricle, great arteries, venae cavae, and pulmonary veins. In these anatomic areas, the definition on MR images was said to be equal to that on angiocardiograms and better than that on echocardiograms, especially in postoperative patients. The few poor-quality studies were due to patients' movements (insufficient sedation), arrhythmias (mis-triggering the slices), and flow artifacts produced by vascular clips and other prosthetic materials [15].

Physiologic data also can be extrapolated from cine GRE sequences, although accurate measurement of pressure gradients and flow rates is mostly experimental at this point. Poststenotic jet velocities up to 6 msec have been measured accurately across native heart valves, conduits, Fontan anastomoses, and aortic coarctations, and the values compare well with those obtained by using Doppler technique [16]. Although cine MR currently is limited in the assessment of the severity of aortic stenosis, flow characteristics have been detected that are associated with the severest degrees of stenosis [17]. Pressure gradients up to 120 mm Hg across valves have been computed from measurements of poststenotic flow velocities. These and other physiologic extrapolations may become useful clinically [18, 19].

MR in the Analysis of Cardiac Function

Complete evaluation of congenital heart disease requires physiologic information. Pressures and saturations within cardiac chambers and great vessels are the most important measurements, and they cannot be measured by using conventional MR techniques. Other determinations of cardiac function (i.e., ejection fraction, ventricular volume) can be measured by using MR and eventually could be useful for quantification of cardiac work and other measurements.

ECG-gated SE techniques can be used to evaluate global ventricular function and regional wall motion, but dynamic evaluation of parameters such as ejection fractions, ventricular volumes, regurgitant fractions, and shunt flows across ventricular septal defects were not routinely practical until GRE cine MR imaging was developed [1, 5, 9]. However, the routine clinical applicability of cine MR imaging for accurate physiologic measurement has yet to be validated. Because the images are not acquired in real time, and because they can be degraded by movement by the patient, arrhythmias, and surgical clips and wires, some caution has been recommended [15]. On the basis of his experience with more than 600 patients, Pettigrew [20] asserted that cine MR was an excellent tool for quantitative and qualitative assessment of the left ventricle; atrioventricular valves; and the right ventricle, a chamber notoriously difficult to evaluate with other means. With these developments, MR imaging has become competitive with echocardiography in the evaluation of hypertrophic changes and other cardiomyopathies [1].

Because of the sluggish flow associated with pulmonary artery hypertension, decreased signal intensity would be expected on GRE images of the pulmonary arteries and in-

creased intensity on SE images. The latter has been reported in pulmonary artery hypertension with systolic pressures greater than 90 mm Hg [20]. Another index of pulmonary perfusion being developed is based on detecting alterations in arterial wall dynamics [21]. Cine MR with GRE techniques also shows promise for evaluation of pulmonary arterial blood flow [18]. Of particular importance in congenital heart disease, measurements of left-to-right shunt ratios comparable to measurements obtained by using radionuclide and cardiac catheterization techniques have been described [22]. Similarly, methods of estimating oxygen saturations from MR imaging are being developed [23].

Current Problems in the Use of MR

Despite all that has been accomplished, and with all the potential promised, there are several reasons why technology as powerful as MR imaging is still complementary to echocardiography and angiocardiography in the diagnosis of congenital heart disease.

Technical Limitations

MR imaging is a relatively immature technologic development; improvements in the devices are certain, but have not occurred yet. The optimal echo sequences probably are yet to be discovered. At the same time, this expensive technology is often so devoted to neurologic and musculoskeletal examinations that MR studies are not seriously considered for patients with congenital heart disease. Perhaps radiologists and pediatric cardiologists need to commit themselves to improving their working relationships and fostering an exchange of technical and clinical information that would increase the usefulness of cardiac MR imaging.

Seeing an entire heart and its chambers in various projections is generally comprehensible to physicians, hence the persistent popularity of angiocardiograms, despite advances in sectional imaging techniques such as echocardiography and MR imaging. When sectional images must be manipulated mentally for physicians to understand the complex anatomy of multiple heart defects, the process is more difficult and the potential for error is greater. Computer-assisted three-dimensional (3D) reconstruction of both MR images and sonograms would most likely enhance their appeal and value to medical and allied workers who care for patients with congenital heart disease.

The MR images obtainable today are not simultaneously optimal for both anatomic and dynamic evaluations; SE images have excellent tissue contrast but low temporal resolution, and GRE images have good temporal resolution but low definition for tissue. Although GRE images are best for functional analysis, they are not "real time" and therefore are subject to sampling errors [15]. MR imaging of congenital heart disease would be greatly strengthened by the availability of a real-time cine MR technique that provided sufficient resolution of cardiovascular tissue to show subtle abnormalities in the cardiac septa and leaflets.

Measurements of cardiac output, myocardial mass, ejection fractions, and other standard parameters are necessary to understand and plan new operations, such as the Fontan procedure, which considerably changes normal anatomy and function. At the same time, replacement of cardiac catheterization by MR techniques will not become a real consideration until pressures [18] and shunt volumes [22] can be extrapolated accurately from MR data.

Clinical Considerations

A number of frustrations are associated with cardiac MR imaging in infants and children with congenital heart disease, and these distract from the appeal of the technology to pediatric cardiologists. The examination times are long, generally 40–50 min, sometimes extending to 90 min. Because movement by the patient severely degrades the images, oral or IV sedation is usually necessary in children less than 10 years old. The sedation requires the additional expense of nursing personnel for administration and monitoring [24]. The length of the gantry and other physical limitations make direct visual monitoring of very ill patients difficult, even when parents or nurses remain in the imaging room. However, the competing methods, echocardiography and cardiac catheterization, are similarly time-consuming and require prolonged sedation.

Increasingly, cardiac MR is being compared with echocardiography [7, 9, 12, 14, 15], but the sensitivity and specificity of MR have yet to be studied by using high-field-strength systems and cine sequences [25].

Competitive Technology

Echocardiography has an anatomic advantage (imaging of cardiac valves) and a competitive capability (Doppler imaging) for functional analysis. Limitations of echocardiography include difficulty imaging parts of the heart distant from the ultrasound probe in large patients, inability to image through air or bone, artifacts caused by prosthetic materials, limited field of view, and the necessity to deduce some spatial relationships. The inability to image vessels and airways simultaneously limits its use in the evaluation of symptomatic vascular rings. Sonography has advantages over MR in that sonographic equipment is compact and mobile and comparatively inexpensive to buy and maintain.

Cardiac catheterization and angiocardiology are well-established procedures that, despite the associated ionizing radiation, vascular catheters, and contrast materials, provide the physiologic and anatomic information needed for evaluation of congenital heart disease.

Future Considerations

Before MR imaging can assume a larger role in the diagnosis and management of patients with congenital heart disease, at least two innovations seem necessary: (1) faster and better imaging sequences should be developed to reduce the amount of sedation required and provide better functional

and anatomic images and (2) on-line reconstruction of real-time MR sectional images, preferably in a 3D format, would make the anatomy more comprehensible. Such images should also facilitate improved functional analysis.

Cardiac MR Imaging System

No MR imaging system designed exclusively for cardiac examinations is commercially available. However, body imaging systems that use technology different from that of current MR devices are being evaluated for their capability of providing improved cardiac studies [26]. If a variation of echoplanar imaging is used, rapid cine MR can be done so that a complete set of cardiac images requires 30 msec or less. The sequences are obtained so rapidly that imaging of the heart is in real time [26]. Current deficiencies are low tissue resolution and the high magnetic field strengths needed to produce the GRE images. It may be several years before the clinical usefulness of this technology is proved.

Improved Sequences and Technology

Higher-field-strength (1.5–2.0 T) magnets, by increasing the signal-to-noise ratio, improve the tissue contrast of SE images but also increase flow artifacts. This complication can be overcome by using spatial presaturation [1]. In addition to real-time cine MR imaging, other developments for improved functional evaluation of the heart are biphasic SE imaging and spatial modulation of magnetization (SPAMM), a tagging of myocardial segments that then can be specifically followed through time and space during the entire cardiac cycle [27–29]. Developing techniques for more rapid imaging will allow use of breath-holding maneuvers in children able to cooperate, which may eliminate the blurring of images caused by respiratory motion.

Noninvasive MR tagging techniques are a useful example of how MR imaging in the evaluation of congenital heart disease could open the door to new thinking about surgical repair of the congenitally malformed heart. Hoffman and Ritman [30, 31] have proposed that by maintaining a constant volume throughout the cardiac cycle, the heart minimizes energy expenditure by pumping blood while limiting the need to move extracardiac structures such as the lung. This constant-volume relationship is maintained in large part by the epicardial apex remaining fixed in space while the atrioventricular valve plane moves like a piston as the atria and the ventricles alternately fill and empty. With the SPAMM technique [29], it has been shown that a differential twisting between apex and base causes a "wringing" of the ventricle, pulling the valve plane toward the apex [32].

Use of the SPAMM technique might enable us to evaluate the congenitally abnormal heart before and after surgery, paying particular attention to the mechanics of the repair [32]. As shown in the right-hand panels of Figure 6, Gupta et al. [33], working within a software environment dubbed VIDA (volumetric image display and analysis), have implemented a module that uses grid intersections within the myocardium from the SPAMM MR imaging technique to evaluate regional

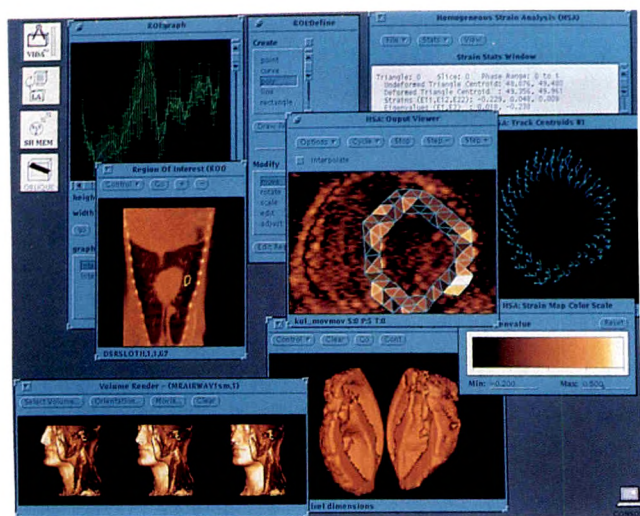


Fig. 6.—Selected modules from imaging software toolbox called VIDA. The program has a unique shared memory structure that allows loading of multiple volume images simultaneously into computer memory. Shown here are region-of-interest module (upper left windows: evaluation of lung field of an animal imaged in Dynamic Spatial Reconstructor), volume-render module (lower left window: facial features of an image data set gathered to evaluate upper airway via MR imaging), general-display module (lower right window: a frame of a movie data set generated by a shaded surface display module that allows visualization of an opened canine heart), and homogeneous-strain module (upper right windows: a short-axis view of a normal human heart imaged by using MR and a SPAMM sequence). In homogeneous-strain module, note that intersection points of stripes have been automatically triangulated and that calculated strain is color coded (color scale is shown in panel in lower right) into triangles. Motion of triangle centroids, through cardiac cycle, is shown in panel labeled Track Centroids. Note wringing motion (twisting and untwisting) in septal and posterior free wall region of left ventricle.

myocardial strain and shear. By taking advantage of the unique properties of MR imaging, analyses such as these could project MR imaging into the mainstream of clinical evaluation.

Three-dimensional Cardiac MR Imaging

Two-dimensional MR images have the disadvantage of requiring mental synthesis of multiple cardiac slices into a coherent image, a task frequently difficult for those not familiar with the tomographic format. Additionally, the anatomic details and complex spatial relationships in patients who have undergone surgical procedures that use prosthetic material are often difficult to show in any two-dimensional format. Advances in computer software that allow creation of 3D images from acquired planar information overcome these difficulties [30]. Two current software packages integrate volumetric image display with quantification without being tied to expensive special-purpose machines: Analyze, developed at the Mayo Clinic, and VIDA, being developed at the University of Pennsylvania (Fig. 6).

Using these (or other) software systems, physicians can currently produce color-coded, sectionable, rotatable 3D MR reconstructions of the heart, great vessels, and mediastinal airways for the evaluation of cardiovascular anomalies (Fig. 7). These images can be produced by acquiring tomographic slices 3–5 mm thick in the axial, coronal, or sagittal plane. The slices are generally obtained in two runs with interslice spacing equal to the slice thickness. Subsequently, the slices can be interleaved to yield contiguous slices, maximizing the signal-to-noise ratio. From the raw data, which are loaded into the system in a 256×256 pixel array, a region of interest containing the heart and great vessels, but excluding much of the lung, chest wall, and abdomen, is chosen by an operator to reduce the need for computer disk space and to speed manipulation. From the two-dimensional axial images of the heart thus obtained, the structures of interest need to be delineated by an operator knowledgeable in cardiac anatomy. This segmentation is accomplished by using interactive binary thresholding. A signal intensity is selected that optimally distinguishes myocardium from cavity. These binary images are processed by using a shape-based interpolation program and

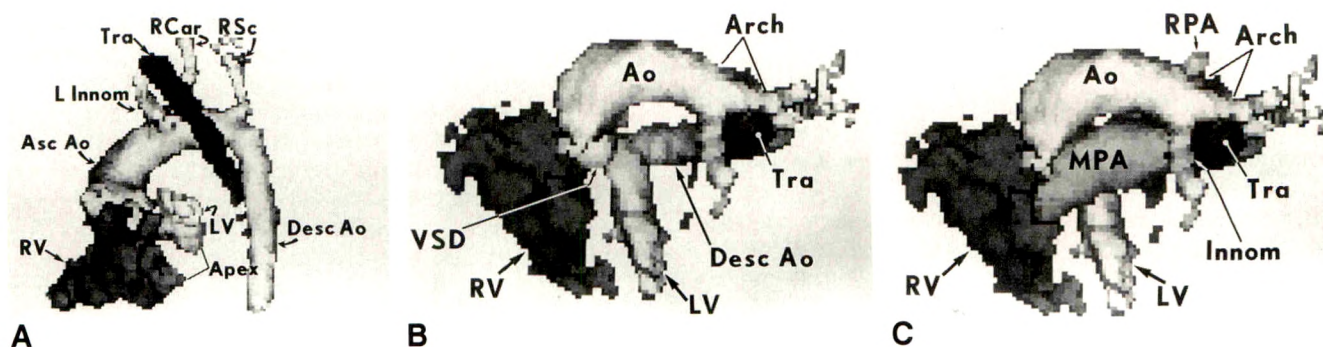


Fig. 7.—Three-dimensional surface display of ventricular and great artery cavities from MR images of patient with tetralogy of Fallot and extreme levoposition of heart.

A, Left posterolateral view. Note posterior orientation of cardiac apex compared with normal orientation of trachea (Tra) and descending aorta (Desc Ao). Asc Ao = ascending aorta, L Innom = left innominate artery (seen in mirror-image right aortic arch), LV = left ventricle, R Car = right carotid artery, R Sc = right subclavian artery, RV = right ventricle.

B, Cranially angled left oblique view of image in A, separating ventricles. Note ventricular septal defect (VSD) beneath aorta (Ao). Trachea (Tra) is seen on end, and position of descending aorta (Desc Ao) passing behind left ventricle (LV) further facilitates orientation. Arch = aortic arch, RV = right ventricle.

C, Same as B, with addition of pulmonary artery. Main pulmonary artery (MPA) arises above right ventricle (RV). Left pulmonary artery is not seen and is probably hypoplastic or absent. Right pulmonary artery (RPA) emerges from beneath aortic arch (Arch). Note left innominate artery (Innom) passing anterior to trachea (Tra).

are then stacked in caudal-to-cephalic order and connected by using a region-growing algorithm [34]. Finally, shading is applied and hidden surfaces are removed.

Three-dimensional reconstructions can be performed in several formats, including display of the cavities only, display of the endocardial surface, contrasting display of the cavities and myocardium, and display of the great arteries and trachea only (in the case of vascular rings or other bronchoarterial abnormalities).

Once the 3D image has been created, it can be rotated around any axis and viewed from any perspective. Others [35] also have successfully depicted the cardiac anatomy and complex spatial relationships in children who have congenital heart defects.

The demonstrable advantages of 3D MR imaging are (1) shortened examination time (sectioning in any plane can be done off-line after just one set of images has been obtained to provide the slices needed for the 3D model), (2) better definition of complex intracardiac spatial relationships (particularly involving septal defects, semilunar valves, and surgical prosthetic materials), (3) improved evaluation of the anatomic relationships between the mediastinal great vessels and the airways (i.e., vascular rings, pulmonary arterial abnormalities), and (4) facilitated communication of the anatomy to those not well versed in interpretation of tomographic images.

Conclusions

MR imaging could revolutionize the evaluation of congenital heart disease. Current sectional imaging and early progress in flow measurement have set the stage for development of on-line 3D reconstruction and extensive functional analysis. Immediate requirements for further progress are high-speed, real-time MR imaging techniques and streamlined, specific software for analysis of cardiac imaging data and measurement of cardiac function and blood flow.

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Dr. DeWees

Stefan C. Schatzki¹

"No woman of any social position in Philadelphia considered herself safe if she could not have DeWees in her confinement." These words of the renowned American surgeon, Dr. Samuel Gross, reflect the reputation enjoyed by Dr. William Potts DeWees, one of the first professors of obstetrics in America, born in Pottstown, PA, in 1768.

In the early nineteenth century, obstetrics received little attention from the medical profession, and most deliveries were carried out by midwives. There was no formal instruction in obstetrics given at the University of Pennsylvania, where DeWees studied; however, he devoted himself not only to the practice of obstetrics but also to teaching, and began to give classes in his office soon after he received his M.D. there in 1806. His work was encouraged by and he received patronage from the famous physician and political leader, Dr. Benjamin Rush. The first chair in obstetrics at the University of Pennsylvania Medical School was established in 1810, but attendance at the lectures in obstetrics was not required for graduation. It was almost 15 years before DeWees became a professor of obstetrics at the University. An additional 9 years would pass before, in 1834, he was appointed chairman of the department. Unfortunately, a stroke compelled him to resign 1 year later. He died in Philadelphia in 1841.

DeWees did much to advance the practice of obstetrics, not only by his skill but particularly by his teaching and publications. He wrote many books about the practice of obstetrics, but his chief work, *A Compendious System of Midwifery*, first published in 1824, was the first authoritative work about obstetrics written in America.

The illustrated portrait of Dr. DeWees, by John Neagle, shows DeWees at the height of his career, 1 year before he became chairman of obstetrics at the University of Pennsylvania Medical School. As was true of many portraits of physicians painted in the early nineteenth century, the painting emphasizes the success of its subject and his intellectual achievements without referring specifically to his profession. The painting bears some resemblance to the works of Neagle's father-in-law, the well-known American portrait painter Thomas Sully.

John Neagle was born while his parents were visiting Boston in 1796. He spent most of his life in Philadelphia, and married the stepdaughter of Thomas Sully, then the reigning portrait painter in that city. Neagle, too, had a successful career painting the portraits of affluent Philadelphians. In 1825, with his reputation growing, he traveled to Boston to seek the advice of Gilbert Stuart, the most influential portrait painter of the day. In addition to giving advice, Stuart allowed Neagle to paint what proved to be the last portrait of him

(Museum of Fine Arts, Boston, MA). In 1830, Neagle was one of the directors of the Pennsylvania Academy of Fine Arts, and he was a founder and president of the Artists' Fund Society. Despite these honors and a successful career, he would be largely unknown today except for his masterpiece, *Pat Lyon at the Forge* (Museum of Fine Arts, Boston, MA), one of the finest portraits of the early nineteenth century. This life-sized painting, which flaunted convention, depicts its subject not as the wealthy engineer he was at the time of the painting, but as the defiant blacksmith of his earlier years.

One interesting footnote to Neagle's portrait of DeWees is the probability that this painting was done as a barter, in exchange for medical services promised to the Neagle family. Neagle died in Philadelphia in 1865.



John Neagle (1796–1865). *William Potts DeWees*, 1833. Oil on Canvas, 57 x 45 in. The University of Pennsylvania School of Medicine, Philadelphia, PA.

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Review Article

CT of the Extraperitoneal Space: Normal Anatomy and Fluid Collections

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Knowledge of the appearance and location of the normal fascial structures surrounding the kidneys and the bladder is the key to proper CT analysis of extraperitoneal fluid collections. Recent studies have shown that the renal fascia and the perirenal space are more complex than previously recognized. An extracapsular renal hematoma, confined against the kidney by the posterior renorenal septum within the perirenal space, can entirely simulate a subcapsular hematoma. Pancreatitis fluid can dissect between the discrete layers that constitute the posterior renal fascia, allowing fluid in the anterior pararenal space to extend posterior to the kidney without directly involving the posterior pararenal space. The umbilicovesical fascia separates the small perivesical space from the potential large reservoir of the prevesical space in the extraperitoneal portion of the pelvis. Fluid in the prevesical space can communicate directly with the retroperitoneal spaces surrounding the kidney. In addition to compartmental localization, CT features of the fluid itself or the presence of ancillary findings such as aortic aneurysm, enlarged pancreas, renal mass, or hydronephrosis will frequently indicate the cause and the extent of most extraperitoneal fluid collections.

Before CT, it was difficult to detect and characterize retroperitoneal (extraperitoneal) fluid collections. Blood, urine, pus, or even pancreatic fluid could accumulate deep to the peritoneum, sometimes in very large volumes, with only subtle abnormalities shown by standard radiologic examinations. Our understanding of the complex anatomy of the retroperitoneum and its pathologic fluid collections is based largely on the pioneering studies by Meyers and associates [1] in the late 1960s and early 1970s. Building on prior cadaveric dissection studies by anatomists, they used anatomic and radio-

graphic studies of cadavers, some with contrast material injected into selected retroperitoneal spaces, to devise and refine a compartmental anatomic basis for radiologic diagnosis of retroperitoneal fluid collections. Meyers has further expanded his concepts and material as part of his widely read textbook, *Dynamic Radiology of the Abdomen: Normal and Pathologic Anatomy* [2].

The information displayed on cadaveric cross sections was used primarily to define fascial boundaries, to establish the basis for the proposed anatomic compartmentalization, and to predict and explain the findings on standard radiographs in patients with proved fluid collections. Despite the elegance and logic of these initial scholarly works, the radiographic findings were subtle, and their application in daily practice was often difficult. It was not until the advent of CT that the full impact and utility of the cross-sectional approach to retroperitoneal fluid collections was fully appreciated. Love, Meyers, and associates [3] affirmed the CT correlates of the latter's initial classification scheme. In this new setting, other studies have furthered our understanding of the anatomic basis of cross-sectional imaging findings in patients with abdominal fluid collections in a series of papers and book chapters correlating clinical imaging studies with new anatomic cadaveric experiments and observations [4, 5].

Although sonography and MR imaging can show extraperitoneal fluid collections, they are much less effective than CT. Sonography is hampered by overlying bowel gas and, more importantly, cannot show fascial planes. MR imaging currently is limited by its higher cost, lengthier examination time, and

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inferior spatial resolution for detection of normal fascial planes. We review the basic compartmental anatomy of the extraperitoneal space and its most common fluid collections as depicted on CT scans. Recent advances in our knowledge are emphasized and areas of controversy are explored.

Renal Fascia

The retroperitoneal space, bounded anteriorly by the posterior parietal peritoneum and posteriorly by the transversalis fascia, extends from the diaphragm superiorly to the pelvis inferiorly. The renal fascia, a collagenous connective tissue sheath that envelops each kidney and its surrounding fatty envelope, serves to define three major compartments: the perirenal space, the anterior pararenal space, and the posterior pararenal space (Figs. 1 and 2). The perirenal space, located between the anterior and posterior layers of renal fascia, contains the kidney, adrenal gland, renal vessels and proximal collecting system, and a variable but usually prominent amount of fat. The anterior pararenal space, lying between the posterior parietal peritoneum anteriorly and the anterior renal and lateroconal fascia posteriorly, contains most of the pancreas and the retroperitoneal portions of the duodenum, ascending colon, and descending colon. Little fat is present in this compartment. The posterior pararenal space,

situated between the posterior renal fascia and lateroconal fascia anteriorly and the transversalis fascia posteriorly, contains a moderate amount of fat and is most notable for its absence of contained organs.

In the medical literature, the term *Gerota's fascia* is frequently used as a general term to describe both the anterior and posterior layers of renal fascia. Named after the investigators who originally described these structures, the posterior layer is sometimes called *Zuckerkandl's fascia* and the anterior layer *Gerota's fascia* [6]. The normal anterior and posterior renal fascia are frequently well visualized on CT scans of patients except when abdominal fat is scant. Studies from the early 1980s reported that on at least one axial slice the anterior and posterior renal fascia are shown on both sides in more than 50% of patients [7]. This number is now undoubtedly higher, owing to the improved resolution of the newer generation scanners. Several CT features of the normal renal fascia are well known: (1) they normally measure 1–3 mm in thickness, (2) the posterior renal fascia is thicker and more frequently visualized than is the anterior layer, and (3) the anterior fascia is more easily identified on the left side than on the right. Thickening of the renal fascia is a sensitive but nonspecific indicator of adjacent contiguous disease, and is seen with both inflammatory and neoplastic disorders [7].

On CT scans, the anterior and posterior layers of renal

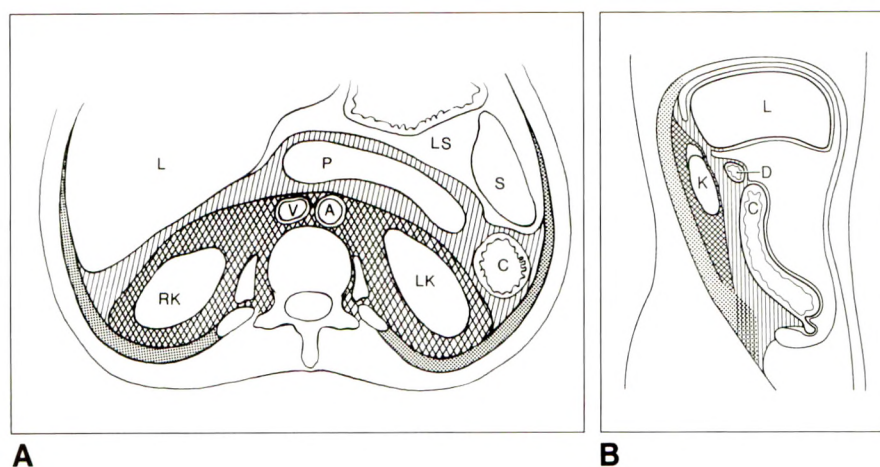


Fig. 1.—A and B, Axial diagram (A) at level of kidneys and sagittal diagram (B) in plane of right kidney show three major retroperitoneal compartments: anterior pararenal space (hatched), perirenal space (cross-hatched), and posterior pararenal space (stippled). L = liver, P = pancreas, LS = lesser sac, S = spleen, V = vena cava, A = aorta, RK = right kidney, LK = left kidney, C = colon, D = duodenum.

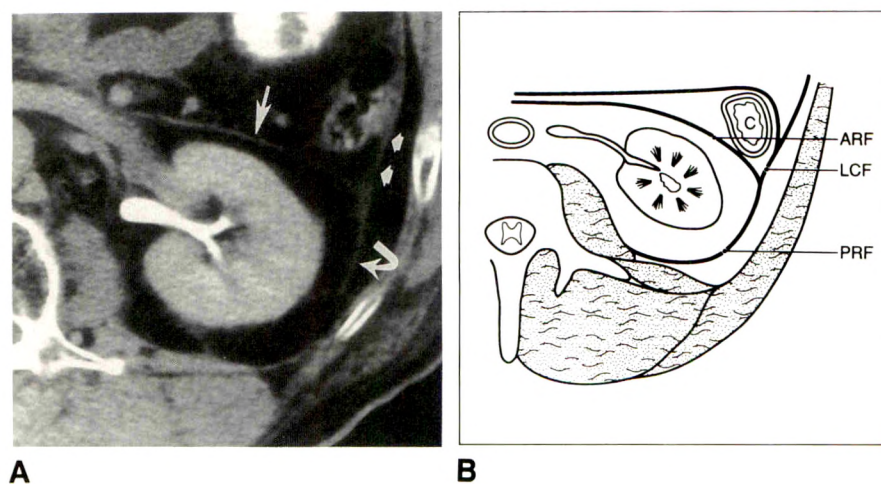


Fig. 2.—A, CT scan at level of left kidney shows anterior renal fascia (long straight arrow), posterior renal fascia (curved arrow), and lateroconal fascia (short arrows).

B, Diagram of same layers of renal fascia. ARF = anterior renal fascia, LCF = lateroconal fascia, PRF = posterior renal fascia.

fascia appear to fuse laterally to form the lateroconal fascia, which then continues anterolaterally behind the colon to blend with the parietal peritoneum. Disagreement exists, however, as to the superior, medial, and inferior extent of the renal fascia [4]. Discrepant results of both anatomic and radiologic studies have raised questions about the patency of the perirenal space both medially and inferiorly.

The junction of the anterior, posterior, and lateroconal fascia assumes a more medial position on axial sections as one progresses in a caudal or inferior direction. The perirenal space narrows so that it resembles an inverted cone when viewed from a frontal projection. This cone of renal fascia and its enclosed perirenal space angles medially toward the lower psoas muscle and blends loosely with the periureteric connective tissue [1]. No consensus exists on the strength or completeness of the inferior and medial fusion of the renal fascia. Because air dissected into the perirenal space when presacral pneumography was performed to image the adrenal glands, inferior anatomic patency of the cone of renal fascia is probably the rule. It is likely, however, that adhesions can form and occlude this opening, because most perirenal space fluid collections do not extend into the extraperitoneal pelvic compartments. Nevertheless, published reports [4] and our own CT observations suggest that inferior patency persists in at least some patients, allowing either inferior extension of perirenal fluid or superior extension of pelvic fluid into the perirenal space [5, 8].

Caudal to the cone of renal fascia, the anterior and posterior pararenal spaces merge. Although not formally designated as a separate compartment in most accounts, it is convenient to refer to this region as the infrarenal retroperitoneal space. It is in direct continuity with the prevesical space and the other extraperitoneal compartments of the pelvis.

The medial attachment of the posterior renal fascia varies depending on the cephalocaudal location of the axial CT slice

and on the width of the quadratus lumborum muscle [9]. Although many diagrams depict this medial insertion near the anterior portion of the psoas muscle, careful analysis shows it more often is attached to the posterior psoas or even the quadratus lumborum muscle [9, 10], especially at the level of the lower pole of the kidney. The precise site of attachment has important implications for compartmental fluid analysis, because it determines whether a fluid collection contiguous to the psoas muscle is in the perirenal or the posterior pararenal space.

The medial extent of the anterior renal fascia is more controversial. Results of anatomic studies alone and other studies using radiologic methods are discrepant as to whether the anterior renal fascia continues across the midline or whether the fascia merges with the connective tissues surrounding the abdominal aorta and inferior vena cava [4, 10]. This question is intimately associated with controversy about the medial extent of the perirenal space, because continuity of the anterior renal fascia across the midline would imply a potential communication between the right and left perirenal spaces. Some researchers describe frequent midline communication of the anterior renal fascia, whereas others, especially those using injection of barium suspensions, conclude that neither the anterior renal fascia nor the perirenal spaces are continuous across the midline.

Kneeland et al. [4] recently addressed these questions in a CT study of fluid collections in the perirenal space of cadavers and clinical patients [4]. In the two cadaveric studies, water injected by hand or water-soluble contrast material that was allowed to drip into the perirenal space was shown to traverse the midline to the contralateral perirenal space at or below the lower poles of the kidneys. Similar findings were shown in 12 selected patients with perirenal space collections without prior trauma or pancreatitis. In the other 20 studies reviewed, of patients with either abundant retroperitoneal fat, thickened

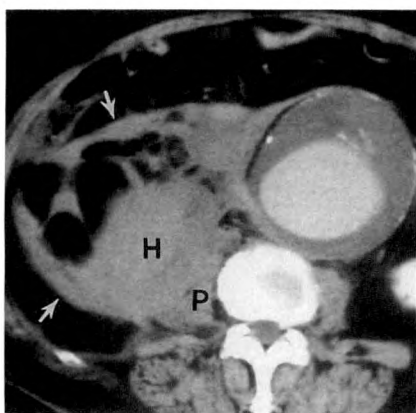


Fig. 3.—Ruptured abdominal aortic aneurysm. CT scan at a level caudal to lower pole of right kidney shows a hematoma (H) from ruptured aneurysm located primarily in perirenal space, bordered by anterior and posterior renal fascia (arrows) and psoas muscle (P).

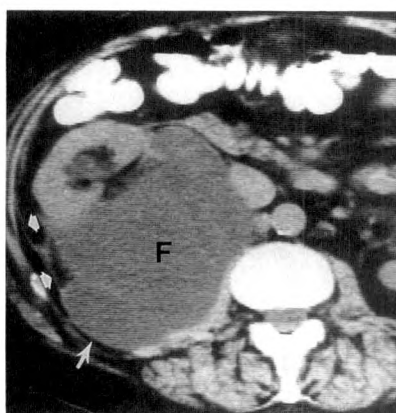


Fig. 4.—Fluid collection in perirenal space. Localization of posterior renal fascia (long arrow) where it abuts fluid collection (F) is inferred from CT scan that shows a contiguous portion of fascia (short arrows) where it is surrounded by fat. Absence of streaky infiltration within compressed fat of posterior pararenal space suggests fluid does not involve that compartment.

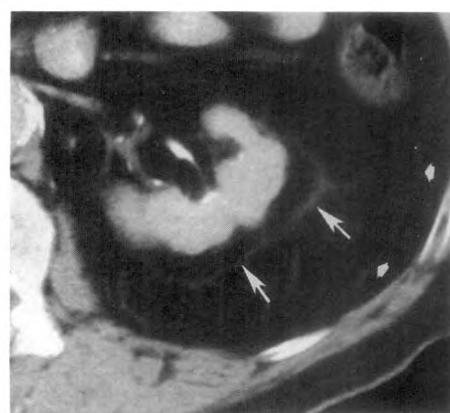


Fig. 5.—CT scan shows posterior renorenal septum (long arrows) extending from anterolateral to posteromedial aspect of kidney. Posterior renal fascia is faintly visible (short arrows).

renal fascia, or both, the anterior renal fascia appeared continuous across the midline in front of the great vessels at the level of the lower third of the kidneys in nearly half the cases. Above this level, clear delineation of this fascial layer and its midline communication decreased in frequency with successively cephalad levels. It was concluded that the perirenal spaces may communicate across the midline, anterior to the lower aorta and vena cava and posterior to the anterior renal fascia at this level. The narrow anteroposterior dimension of the communicating channel may explain why previous anatomic-radiographic studies using thicker barium suspensions did not describe a midline connection between the perirenal spaces.

These observations suggest that the lower abdominal aorta and vena cava are located, in effect, within the midline communication of the perirenal spaces, and that hematomas from ruptured aortic aneurysms extend mainly into the perirenal spaces [4, 11]. Other authors have disputed this contention, claiming that aortic aneurysms typically rupture into the psoas muscle, and then—with increasing pressure—into the posterior pararenal space rather than the perirenal space [12]. Compartmentalization of the hematoma from a ruptured abdominal aortic aneurysm probably depends on the site of rupture, both circumferentially and longitudinally, as well as on the configuration of the anterior renal fascia and the perivascular connective tissue. Although a small fraction of aortic aneurysms *do* rupture into the psoas muscle [13], we believe that most cases show a preponderance of the blood in the perirenal space (Fig. 3). The lack of involvement of the psoas muscle in most cases is easiest to see on scans obtained without IV injection of contrast material, where the high density of an acute hematoma (50–80 H) relative to the normal psoas muscle (30–40 H) makes it easy to identify the margin between the normal psoas muscle and the adjacent hematoma. The distribution of perirenal blood from a ruptured abdominal aortic aneurysm is similar to the distribution of perirenal fluid from other causes, except that the perivascular fat posterior and lateral to the aorta and vena cava is more often infiltrated in cases due to aortic rupture. The presence of smaller amounts of blood in the pararenal spaces or even the intraperitoneal spaces in some patients may relate, in part, to mechanical disruption of the renal fascia by blood under high pressure within the perirenal space.

Recent evidence suggests that the posterior renal fascia, rather than a single structure, consists of two major layers or laminae. In an elegant anatomic study using unembalmed cadavers, Raptopoulos et al. [9] showed convincingly that this fascial layer consists of a thicker posterior lamina and a thinner anterior lamina. The two layers diverge anterolaterally; the anterior lamina continues as the anterior renal fascia, whereas the posterior lamina continues as the lateroconal fascia. This hypothesis was buttressed by their observation, on both in vivo CT scans and unembalmed cadavers, that the anterior and posterior layers of renal fascia generally form a smooth continuum parallel to the renal contour, rather than join at an acute angle at the origin of the lateroconal fascia. These concepts of fascial structure and anatomy were used to explain the wedge-shaped contour of retrorenal fluid collections so often seen posterior to the left kidney in acute pancreatitis.

Compartmental Analysis

The layers of renal fascia can be detected and identified when they are bordered on both sides by fatty tissue. They are seen most frequently in adults with abundant retroperitoneal fat, and less often in children and in emaciated adults. When fluid in a retroperitoneal compartment abuts the entire extent of one of the layers of renal fascia, the fascia itself is usually obscured and it may be difficult to determine which compartment is involved. The margin of a fluid collection that is straight and sharply defined is assumed to represent the fascial margin, whereas the interface between fluid and fat within the compartment usually has an uneven and feathery or spiculated appearance. If fluid abuts only a portion of the fascia on an axial CT scan, one can estimate the likely location of the fascia at that site by assuming it continues in a relatively straight and uninterrupted course (Fig. 4). This type of analysis helps explain why localization of fluid to the right anterior pararenal space can be the most difficult, as this compartment contains very little fat, and the right anterior renal fascia itself is often difficult to identify. It is also clear that this method of analysis can be problematic when fluid is present in two adjacent compartments that border a single layer of renal fascia.

Localization of retroperitoneal fluid to a specific anatomic compartment has other pitfalls. The renal fascial layers may not be intact in all patients. In some cases this could be due to developmental variation resulting in incomplete formation, or even complete absence, of one or more layers. More often, the fascia may be interrupted by traumatic disruption, by pressure from a ruptured abdominal aorta or other major artery, or by dissolution caused by infected fluid or enzymatic digestion. Whatever the cause of disruption of the renal fascia, the presence of fluid in more than one compartment will complicate analysis of its location, and differential diagnosis may become more difficult.

Extraperitoneal Fluid

Extraperitoneal fluid collections typically consist of blood, pus, urine, lymph, or pancreatic fluid. Except for acute or subacute hemorrhage, these different collections are usually indistinguishable on CT scans, displaying a homogeneous attenuation value near that of water. The presence of extraluminal gas, in the form of gas bubbles or an air-fluid level, usually signifies an abscess caused by a gas-forming organism or an enteric communication. Fresh blood typically has a homogeneous attenuation value of 50–80 H. On unenhanced CT scans, the high-attenuation blood stands out in stark contrast to the adjacent organs and is immediately identifiable and quickly characterized. After IV injection of contrast material, however, enhancement of adjacent organs sometimes makes it difficult to recognize the high attenuation of retroperitoneal blood, so it is often advisable to measure the attenuation of abdominal fluid on enhanced CT examinations. In the subacute state, usually 5–15 days after hemorrhage, cloudlike clumps of high-attenuation material are usually intermingled with surrounding water-density fluid.

Retroperitoneal hemorrhage can be detected and localized to any of the extraperitoneal compartments or to more than one compartment by using CT. One can often predict which

compartment a hemorrhage is in from the clinical history; conversely, anatomic localization by CT, along with assessment of other pertinent features, often allows accurate prediction of the clinical history. Urinomas are most frequently localized to the perirenal space. Abscess or infected fluid can be found in any of the compartments. Extrapaneatic fluid collections associated with pancreatitis, including well-circumscribed pseudocysts, are most common in the anterior perirenal space, but are notorious for crossing fascial boundaries and can be found in all retroperitoneal compartments. Except for high-attenuation collections indicating an acute or subacute hematoma, some retroperitoneal fluid collections will require percutaneous aspiration for definitive diagnosis.

Perirenal Space

The perirenal space is the largest of the three retroperitoneal compartments, and on CT scans it is easily identified as a distinct space in almost all patients. Although the fat within the perirenal space is often depicted as a featureless component, some anatomic textbooks mention weak trabeculae that connect the renal capsule to the renal fascia, and on CT scans Feldberg [14] noted linear structures within the normal perirenal fat. Kunin [15], however, first systematically described multiple fibrous lamellae or septa that divide the region into different compartments. Although these bridging septa are occasionally visible on CT scans of normal perirenal fat, they are more easily visualized when they become thickened by fluid or by other abnormalities. Some of these septa connect the anterior to the posterior leaves of the renal fascia, others arise from the renal capsule and extend to the fascia, and still others arise from the capsule and are arranged more or less parallel to the renal surface. Among the last group is the so-called posterior renorenal septum, a structure running from the anterolateral to the posteromedial aspect of the renal capsule (Fig. 5). With careful scrutiny, the renorenal septum can probably be detected in about 10% of abdominal CT examinations.

Before the posterior renorenal septum was recognized, it was thought that subcapsular and extracapsular hematoma would be easily distinguished on CT scans. A subcapsular hematoma was immediately contiguous to the renal parenchyma, usually flattening its normal convex border, and typically preserving a layer of perirenal fat between its peripheral edge and the nearby renal fascia. An extracapsular perirenal hematoma, on the other hand, typically preserved a layer of fat between its inner border and the edge of the renal parenchyma and was usually contiguous with the renal fascia. Kunin [15], however, showed that the posterior renorenal septum can confine an extracapsular hematoma and deform the renal parenchyma in a manner that can easily mimic the appearance of a subcapsular collection. Distinction of a subcapsular hematoma from an extracapsular hematoma confined by the posterior renorenal septum is usually difficult. The subcapsular location of a hematoma can be predicted with confidence only if the posterior renorenal septum is identified as a distinct structure, separated by a layer of fat from the outer border of the hematoma [16] (Fig. 6).

When confined primarily to the perirenal space, acute hemorrhage is often due to blunt abdominal trauma or to a

ruptured abdominal aortic aneurysm. In the presence of an abdominal aortic aneurysm, identification of acute hemorrhage in the perirenal space is diagnostic of aneurysmal rupture [11]. Interruption of the distinct calcified or noncalcified wall of the aneurysm is often identifiable and usually indicates the site of rupture [17]. Blunt abdominal trauma is another common cause of acute perirenal hemorrhage, often associated with renal contusion, laceration, or infarction. A combination of history, physical findings, and CT features often easily leads to a correct diagnosis in these two common disorders. CT features include high-attenuation material interspersed with fat in the perirenal space. With the patient supine, the blood typically assumes a dependent crescent-shaped configuration within the posterior portion of this compartment. Like most perirenal fluid collections, the blood is usually margined posterolaterally by the posterior renal fascia and posteromedially by the psoas muscle. The perirenal fat often has a spiculated or feathery appearance as the fluid spreads along the underlying network of septa.

Spontaneous subcapsular and perirenal hematomas are uncommon but clinically important, because they often indicate an underlying renal neoplasm. Renal cell carcinoma (Fig. 7) and renal angiomyolipoma are each the cause in about 30% of cases; the remaining cases are caused by a variety of vascular, inflammatory, cystic, and hematologic disorders [18]. Belville et al. [19] recently reported a large series of cases evaluated with CT. Initial CT examinations showed a distinct mass in 12 (67%) of the 18 cases, with CT characteristics that suggested the correct diagnosis in 11 cases. In the other six patients (33%), a discrete mass was not seen, and the cause of hemorrhage was not clear in five of the six. Two of the five underwent follow-up CT, which showed renal cell carcinoma in both. In the remaining three patients who had no CT follow-up, exploratory surgery showed a 1.5-cm renal cell carcinoma in one, a 5-cm angiomyolipoma in the second, and no abnormality in the third.

For patients with a spontaneous perirenal hematoma in whom a mass is not detected on initial CT, serial renal CT examinations are an alternative to exploratory surgery in order to avoid unnecessary nephrectomy in patients with benign disease or no renal disease. Such an approach, of course, necessitates follow-up studies until the hematoma is completely resorbed or until a specific cause is detected and characterized. As Bosniak [18] has emphasized, meticulous attention to optimal CT technique is mandatory, because small renal cell carcinomas can otherwise escape detection. CT must be selectively performed using thin (5 mm or less) sections, both before and after IV injection of a bolus of contrast material.

When urine continues to leak into the retroperitoneal space, an encapsulated collection of large proportion can develop. This collection is commonly termed a urinoma [20], but many other names have been used, including uriniferous perirenal pseudocyst [21]. Obstructive uropathy is the most common cause, but both abdominal trauma and surgical or diagnostic instrumentation also can lead to urinary extravasation. Prior reports have emphasized the frequent temporal remoteness of the cause of urinoma from its detection [20]. As ureteral obstruction is often decompressed by forniceal rupture and pyelosinus backflow [22], it is not surprising that a urinoma

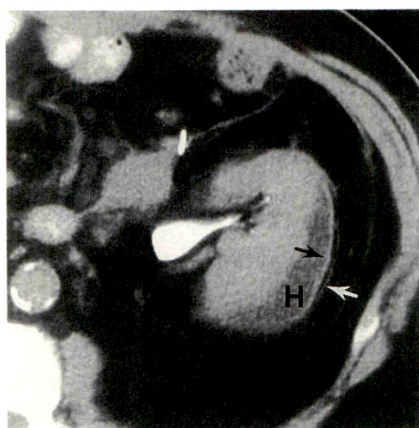


Fig. 6.—Subcapsular renal hematoma. CT scan shows that posterior renorenal septum (white arrow) is separated by a thin layer of fat from hematoma (H) and thickened renal capsule (black arrow).

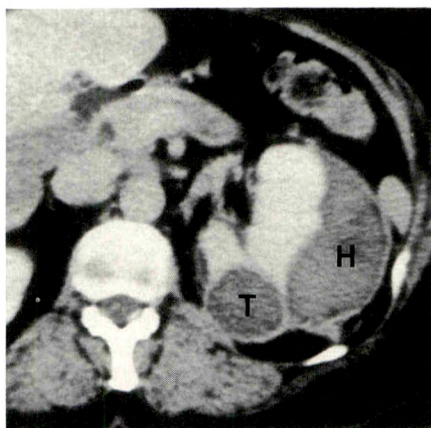


Fig. 7.—CT scan of perirenal or subcapsular renal hematoma due to a ruptured renal cell carcinoma. Rounded carcinoma (T) is similar in appearance to adjacent hematoma (H).

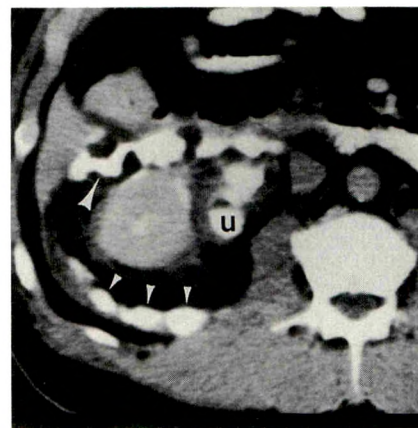


Fig. 8.—Perirenal urinoma. Delayed CT scan 15 min after IV injection of contrast material shows loculations of extravasated contrast material (arrowheads) adjacent to dilated right ureter (u) and in periphery of right perirenal space.

is typically located in the perirenal space. The wall of a urinoma, formed by the surrounding renal fascia, is visibly thickened on CT, reflecting the fibrotic inflammatory process induced by a chronic urine collection [21]. A dilated renal collecting system is seen in virtually all cases in which the urinoma is confined to the perirenal space. Unenhanced CT will usually show a fluid collection of water attenuation, but after IV injection of contrast material, attenuation can increase progressively as urine opacified with contrast medium enters the urinoma [21] (Fig. 8). In these cases the contrast medium may layer within the dependent portion of the urinoma. Although the size of urinomas varies, they are sometimes massive, representing some of the largest perirenal fluid collections. Infrequently, urinomas accumulate in locations outside the perirenal space, usually because of ureteral disruption caused by surgery, instrumentation, or penetrating injuries inferior or distal to the confines of the renal fascia.

Anterior Pararenal Space

Unlike the perirenal and posterior pararenal spaces, the anterior pararenal space contains so little fat that it is difficult to identify as a distinct compartment on CT except at the sites where it contains the alimentary tract structures or unless it is distended by fluid. The very existence of a distinct anterior pararenal space compartment within the retroperitoneum has been challenged, largely on developmental grounds, by Dodds et al. [23], who emphasized its embryologic origin as an intraperitoneal compartment. Most authorities, however, have not supported Dodds' hypothesis [24].

Fluid collections in the anterior pararenal space are more common on the left side, where they are almost always associated with inflammatory disease of the pancreatic tail. When found in the right anterior pararenal space, fluid is usually due to either pancreatic inflammatory disease or to duodenal injury or perforation. Duodenal perforation can be caused by peptic disease, trauma, or instrumentation (especially endoscopic sphincterotomy). Fluid in the left anterior

pararenal space is usually easy to detect. It often silhouettes all or most of the anterior renal fascia on CT and will usually efface the posteromedial aspect of the descending colon. Detection of fluid in the right anterior pararenal space is more subtle and difficult to identify: the anterior renal fascia is not easy to identify without fluid, and when present the fluid does not always distribute itself along the fascia. Fluid is often localized to the anterior pararenal space simply by being situated between the liver, gallbladder, kidney, and duodenum. The presence of gas within the right anterior pararenal space after trauma or sphincterotomy is virtually diagnostic of a duodenal perforation (Fig. 9). We are uncertain if the presence of fluid alone, without associated gas bubbles, can result from duodenal injury without perforation, thus allowing conservative management rather than surgical intervention.

Because the anterior and posterior pararenal spaces converge within the pelvis below the cone of renal fascia, it has been thought that pancreatitis fluid migrated inferiorly in the anterior pararenal space and then superiorly in the posterior pararenal space; this would explain the fluid commonly seen posterior to the left kidney. Raptopoulos et al. [9], however, have argued convincingly that small septal fibers, connecting the lateroconal to the anterior renal fascia, are probably disrupted by proteolytic enzymes in severe acute pancreatitis, resulting in retrorenal extension of fluid into the potential cleft between the two major layers of the posterior renal fascia. This produces the characteristic wedge-shaped appearance of the retrorenal fluid, with compression but preservation of the fat within the posterior pararenal space (Fig. 10). Thus, although it simulates fluid in the posterior pararenal space, the pancreatitis fluid posterior to the kidney actually remains in the anterior pararenal space. This has obvious clinical implications if percutaneous fluid drainage is considered. Fluid within the posterior pararenal space itself, although unusual in acute pancreatitis, may occur via communication between the anterior and posterior pararenal spaces below the cone of renal fascia (as described earlier) or via enzymatic disruption of the lateroconal fascia, allowing direct contiguous extension.

Posterior Pararenal Space

The posterior pararenal space is rarely the site of an isolated fluid collection because it contains only fat. As described earlier, it is uncommonly involved in cases of severe acute pancreatitis. It is occasionally the site of spontaneous hemorrhage in patients on anticoagulation therapy or with a bleeding diathesis, often in association with blood in other extraperitoneal compartments. The posterior pararenal space can also be involved by extraperitoneal hemorrhage that occurs after percutaneous catheterization procedures via the femoral vessels, most commonly cardiac catheterization [8]. Blood is thought to extend superiorly from the perivascular sheath via the prevesical extraperitoneal space to the infrarenal retroperitoneum, and then into the posterior pararenal, anterior pararenal, or perirenal spaces. Similar extension of pus from an extraperitoneal pelvic abscess can occur. Blood in the posterior pararenal space from a ruptured aortic aneurysm is usually overshadowed by the much larger amount in the perirenal space.

Pelvic Extraperitoneal Space

Assessment of fluid in the extraperitoneal compartments of the pelvis and its differentiation from peritoneal collections is best accomplished by an understanding of the pertinent fascial planes. More complex and less well known than the more cephalic retroperitoneal counterparts, the pelvic fascia and associated compartments were comprehensively described by Auh et al. [5]. Their descriptions were based on a review of previous anatomic reports, a study of anatomic sections and cadaveric injections, and clinical observations with CT and sonography.

Anterior to the peritoneum and posterior to the transversalis fascia, the umbilicovesical fascia spreads inferiorly from the umbilicus to surround the urachus, obliterated umbilical arter-

ies, and urinary bladder [5]. In a manner analogous to the renal fascia, the umbilicovesical fascia divides the anterior extraperitoneal fat into a perivesical space and a prevesical space. The perivesical space, containing the bladder, umbilical arteries, and urachus, is analogous to the perirenal space. The prevesical space, located anterior and lateral to the umbilicovesical fascia, is analogous to the anterior pararenal space. This huge potential compartment extends superiorly up to the umbilicus; posterior to the pubis it is known as the space of Retzius. At the level of the bladder dome, the umbilicovesical fascia is frequently seen on axial CT scans as it indents the contiguous anterior parietal peritoneum as part of the medial umbilical folds [5].

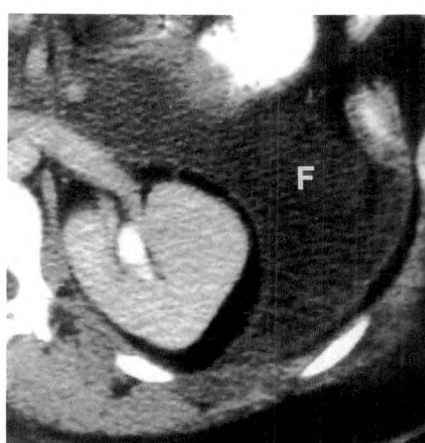
Auh et al. [5] have characterized extraperitoneal pelvic fluid collections as assuming a "molar-tooth" configuration (Fig. 11A). The "crown" portion of the molar tooth lies anterior to the urinary bladder, between the umbilicovesical fascia and transversalis fascia of the anterior abdominal wall, and displaces the bladder posteriorly. The "root" portion of the molar tooth extends posteriorly, between the fascia and either the peritoneum superiorly or the parietal pelvic fascia inferiorly. As the "roots" are frequently asymmetric, the bladder is often displaced away from the midline by large extraperitoneal pelvic fluid collections (Fig. 11B).

The prevesical extraperitoneal compartment is directly continuous with the infrarenal retroperitoneal compartment below the cone of renal fascia. Fluid collections in this infrarenal space frequently extend into the ipsilateral aspect of the prevesical space: in this location it can be misinterpreted as being within the peritoneal portion of the pelvis [5]. Additionally, extraperitoneal fluid collections arising in the pelvis can extend, via the prevesical space, superiorly into the retroperitoneal compartments of the abdomen (Fig. 12). The prevesical space is also continuous with the rectus sheath, the presacral space, and the femoral sheath.

Retroperitoneal hematoma is a significant complication of



Fig. 9.—Abscess in anterior pararenal space. CT scan shows fluid and gas bubbles (A) between duodenum, liver, and right kidney. Anterior renal fascia (arrows) forms posterior border of abscess. Intraperitoneal ascites surrounds liver.

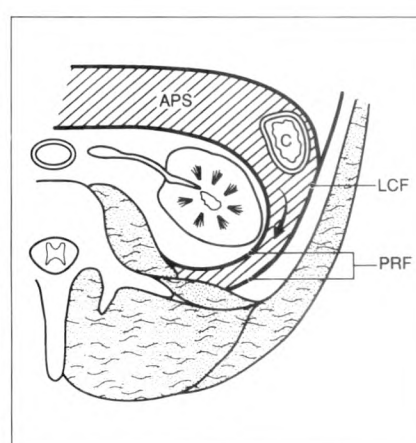


A

Fig. 10.—Retrorenal extension of pancreatitis fluid.

A, CT scan shows fluid (F) in left anterior pararenal space extending posterior to kidney, producing a characteristic wedge-shaped appearance.

B, Diagram shows fluid (hatched area) dissecting layers of posterior renal fascia. APS = anterior pararenal space, C = descending colon, LCF = lateroconal fascia, PRF = two layers of posterior renal fascia.



B

a variety of femoral vascular catheterization procedures. Tretola et al. [8] recently described the CT findings and clinical data in 21 patients with significant hemorrhagic complications after catheterization. Hematoma was shown by CT in the following locations: retroperitoneum (12/21), peritoneum (3/21), groin and thigh (8/21), and abdominal wall (5/21). The distribution of hematomas was explained by elaboration and extrapolation of the discussion by Auh et al. [5]. The femoral sheath, containing the femoral artery and vein, opens directly into the prevesical extraperitoneal compartment. Blood in the prevesical space can spread superiorly and posteriorly, deep to the parietal peritoneum, into the infrarenal retroperitoneal space, and then further superiorly into the perirenal, anterior pararenal, posterior pararenal, or ileopsoas compartments. Alternatively, blood reaching the prevesical space via the femoral sheath can also ascend anteriorly just beneath the transversalis fascia to the anterior abdominal wall. The rectus abdominis and other abdominal wall muscles can be more directly involved owing to direct extension of the blood, either through the thin transversalis fascia or along the epigastric vessel sheaths penetrating the fascia. These speculations assume that the extraperitoneal hematomas in these patients are always due to femoral vascular injury, which then spreads to other regions via direct communication. As most of these patients are receiving anticoagulant or thrombolytic therapy, however, one could speculate that at least some of these hematomas are induced by the medications themselves and might not originate in the femoral sheath.

Psoas Muscle

The psoas muscle is a frequent site of retroperitoneal abscesses and hematomas, and it is intimately associated with the renal fascia and the perirenal and pararenal spaces. Originating from the transverse processes of the 12th thoracic vertebra and all the lumbar vertebrae, the psoas muscle

extends inferiorly in a paraspinous location. Fusing with the iliacus muscle in the pelvis, it then passes as the ileopsoas muscle beneath the inguinal ligament to insert on the lesser trochanter of the femur [25]. Because its superior portion passes beneath the arcuate ligament of the diaphragm, the psoas muscle extends from the mediastinum to the thigh. A fascial membrane protects the psoas muscle from surrounding disease: thus the psoas muscle is sometimes referred to as a retrofascial structure. In the upper and middle portions of the abdomen, the psoas muscle margins the medial aspect of the fat within the perirenal space. It is also contiguous, at some levels and to a lesser extent, with the posterior pararenal space.

Although occasionally idiopathic, abscesses in the psoas muscle are frequently caused by direct spread of adjacent infection, usually from the spine or disk space or from the gastrointestinal tract in patients with diverticulitis, Crohn's disease, or complicated appendicitis [26]. Renal infections frequently extend directly into the adjacent perirenal space, and from there the infection can spread directly through the perirenal fat to involve the psoas muscle. The opposite pathway, spread of infection from a primary abscess in the psoas muscle to involve the perirenal or pararenal spaces, rarely occurs. Most infections of the psoas muscle are now caused by pyogenic organisms rather than by tuberculosis [25–27].

The psoas muscle is commonly the site of a significant retroperitoneal hematoma, especially in patients with a bleeding diathesis or who are receiving anticoagulant medications. Rarely, a ruptured abdominal aortic aneurysm can bleed directly into the psoas muscle rather than the perirenal space. Hemorrhage in the adjacent perirenal or pararenal compartments is sometimes associated with a hematoma in the psoas muscle.

On CT scans, the presence of a hematoma or abscess in the psoas muscle is usually associated with diffuse enlargement of the muscle. An acute hematoma will typically have a

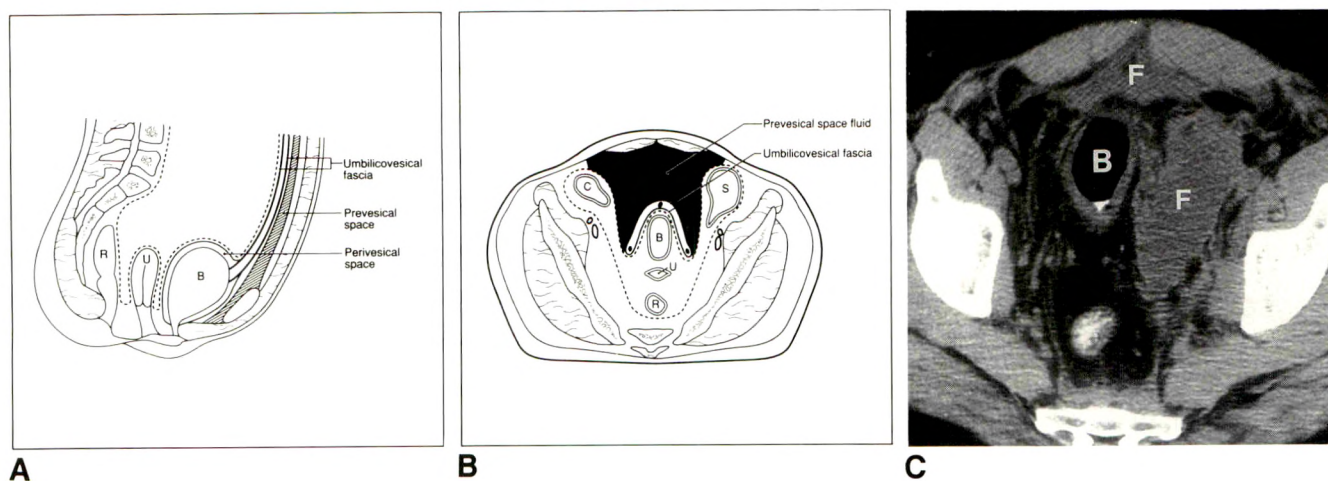


Fig. 11.—Fluid in prevesical space.

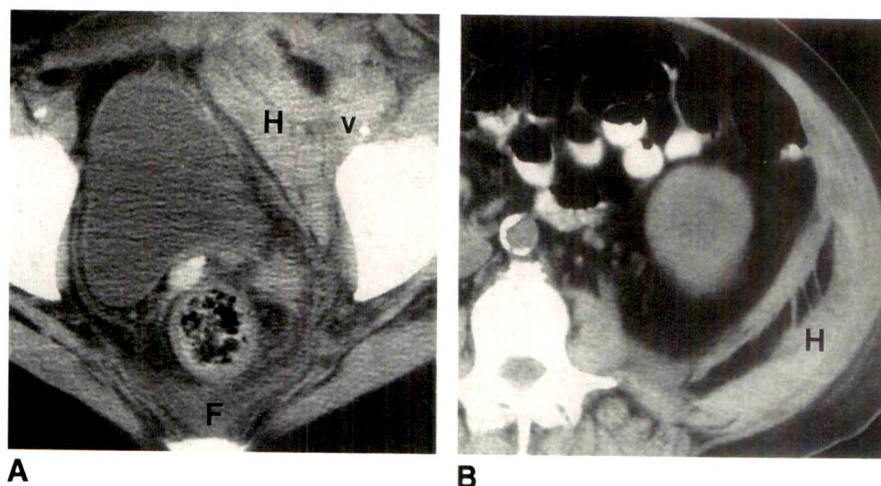
A and B, Sagittal diagram (A) of lower abdomen and pelvis shows umbilicovesical fascia, prevesical space, and perivesical space. Axial diagram (B) shows large fluid collection distending and enlarging prevesical space, producing a characteristic molar-tooth configuration. Both diagrams modified from Auh et al. [5]. R = rectum, U = uterus, B = bladder, C = cecum, S = sigmoid, dotted line = peritoneum.

C, CT scan shows fluid (F) in prevesical space, anterior and lateral to gas-containing bladder (B). Umbilicovesical fascia forms posterior and medial margins of these collections.

Fig. 12.—Extraperitoneal hematoma associated with femoral vascular catheterization and anticoagulation.

A, CT scan shows hematoma (H) in left side of prevesical space abutting and obscuring left femoral vessels (v). Fluid (F) is present in retrorectal presacral extension of prevesical space also.

B, CT scan shows that hematoma (H) also involves left posterior pararenal space.



focal region of high attenuation to indicate the presence of fresh blood, whereas an abscess will usually show a central low-density area, especially on contrast-enhanced scans. Although uncommonly seen, gas bubbles in a psoas fluid collection are virtually pathognomonic of abscess. When an abscess in the psoas muscle is caused by direct extension of a renal abscess, the CT findings typical of a renal and perirenal inflammatory lesion should be visible. Any neoplasm that originates in or metastasizes to the retroperitoneum can involve the psoas muscle either by blood-borne metastasis or by extension from adjacent malignant lymph nodes, and occasionally such a malignant lesion, especially if necrotic, can be indistinguishable on CT scans from an abscess or a hematoma in the psoas muscle.

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Book Review

Basic Doppler Physics. By Hans-Jørgen Smith and James A. Zagzebski. Madison, WI: Medical Physics Publishing, 121 pp., 1991. \$39

This book is intended for residents, radiologists, and sonographers who are familiar with B-mode sonography but have little or no knowledge of Doppler physics, or physics in general. It is divided into two major sections: basic Doppler physics and color flow imaging. Twelve of the 17 chapters deal with basic Doppler physics. Each of the chapters is brief and deals with a single basic concept. The book progresses chapter by chapter from first principles to more complicated explanations of Doppler physics, signal processing, and spectral analysis. Numerous diagrams help clarify such phenomena as aliasing and the factors that dictate pulse repetition frequency. A useful discussion of methods to prevent aliasing is included. Chapter 6 contains a brief but comprehensive discussion of Doppler signal processing.

Chapters 9, 10, and 11 discuss Shannon's sampling theory and how it relates to the phenomenon of Doppler aliasing. Chapter 12 deals with the techniques and sources of error inherent in volumetric blood-flow calculations.

The second section, which deals with color flow imaging, begins with an introduction to the instrumentation of B-mode gray-scale real-time imaging. Different transducer and signal-processing configurations are diagrammed, and the basic working principles are explained. Scanning speed and frame rate limitations are described. The concept of dynamic focusing is presented with helpful diagrams. Color flow aliasing is presented in Chapter 16. All color flow images in this discussion were obtained by using a Doppler phantom. The final chapter deals with the fairly recent concept of time-domain correlation as a method of estimating blood-flow velocity. This process, which is a variation of the techniques used in "color velocity imaging," has recently been introduced in a commercially available unit. This technique uses an analysis of multiple echoes transmitted at very short

intervals. The pattern of reflectors obtained from returning pulses is subjected to a time-domain correlation method, which is used to extract a time change that best matches echo signatures from sequential pulses. The time change is correlated with the Doppler pulse rate in order to obtain an estimation of blood-flow velocity. The potential advantages of time-domain velocity estimations include improved color Doppler resolution and decreased or absent aliasing. Other potential advantages include lower power output and the potential for real-time volumetric flow estimations.

Although the design and content of this text make it a potentially useful text for beginners, the entire manuscript is filled with misspellings, incorrect terminology, and incorrect statements. After I had read this manuscript with some concern and dismay over the apparent lack of proofreading that resulted in these incorrect and misleading statements, a two-page errata statement arrived from the publisher. The publisher has stated that it intends to append this errata sheet to the front of the text. I find this quite disturbing and think it is unfair to ask a reader to refer to an errata sheet more than 50 times during the reading of a text that is only 121 pages long. Furthermore, a beginning student of Doppler physics might not recognize an incorrect statement and therefore would not automatically know to refer to the errata sheets. Consequently, the potential reader would be forced to take the errata sheet and go through the book correcting mistakes. This is unacceptable. The authors and publisher should combine their efforts to correct all these obvious errors and come up with a second edition.

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Review Article

Color Doppler Imaging of the Hepatic Vasculature

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Duplex sonography added a new dimension to real-time sonographic imaging and can be used to characterize flow dynamics. Unfortunately, duplex sonography also has significant drawbacks, most of which are the result of the limited sampling ability of pulse-gated technology and the inability to provide a global display of Doppler information. Sonographic imaging of intraabdominal vessels has improved markedly with the advent of color Doppler techniques. This article reviews the use of color Doppler sonography in the evaluation of hepatic vessels. The complementary role of Doppler spectral analysis is also considered.

Technique

Evaluation of the hepatic vasculature with Doppler sonography is performed after a thorough examination of the parenchyma of the liver. Parenchymal processes often underlie vascular abnormalities, and primary vascular diseases almost invariably have a significant effect on the parenchyma. Transducers with a sector format are best for scanning the upper abdomen. The small area of contact facilitates positioning of the transducer and intercostal access, both of which are essential if adequate Doppler angles are to be maintained. For most adults, a 3.5-MHz or lower frequency transducer should be used for hepatic vascular imaging. Transducers of higher frequency are inadequate for penetration of the upper abdomen by the ultrasound beam. Lower frequency transducers (2–2.25 MHz) are preferable; Doppler sensitivity is increased considerably with little degrading effect on resolution. Depending on the equipment used, optimum real-time

imaging may require a different transducer than is used for the Doppler examination.

Positioning of the transducer varies with the vessel under study. (Specific details about techniques related to individual vessels are discussed later.) An optimum Doppler angle should be maintained whenever possible. In the upper abdomen, obtaining a Doppler angle of less than 60° may be difficult. Vessels are often perpendicular to the Doppler beam, and access may be limited. In some cases, scanning must be done from several directions in order to decrease the Doppler angle and optimize signal reception. Having the patient fast beforehand is not essential when the intrahepatic vasculature is evaluated, and actually may be detrimental in studies of the portal vein. A recent investigation [1] has shown increased portal vein velocity after meals; postprandial scanning may be better for showing small portal veins or those with very slow flow. It is essential that the patient's stomach be gas-free (either empty or fluid-filled) when attempts are made to visualize extrahepatic vessels such as the splenic or superior mesenteric veins or the hepatic artery between the portal hepatis and the celiac axis.

The Hepatic Artery

The hepatic artery typically originates as one of three major branches of the celiac axis. The common hepatic artery initially courses over the anterior superior edge of the pancreas and, after giving off the gastroduodenal artery, runs cephalad as

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the proper hepatic artery with the portal vein and common bile duct into the porta hepatis. In most cases, the hepatic artery lies anteromedial to the portal vein. Almost 50% of patients, however, have some form of anatomic variation or aberrant origin of the hepatic artery. Aberrant hepatic arteries typically take one of two forms: accessory or replaced. The former implies the presence of an extra hepatic artery, whereas the latter is merely a substitute for the "normal" vessel. Of the two, replaced arteries are more common, and in both cases, the anomalous origin varies, depending on whether the right or left hepatic artery is affected. On the right, the superior mesenteric artery most commonly gives rise to the aberrant artery; on the left, the artery almost always arises from the left gastric artery. Aberrant hepatic arteries often lie *dorsal* to the portal vein [2].

The extrahepatic portions of the hepatic artery are often best visualized by detecting the celiac axis anterior to the aorta and following the branch that runs to the right. If the artery is located beneath the portal vein, an aberrant origin should be considered. In the porta hepatis, the common hepatic artery is easily visualized in most cases anterior to the portal vein when scanning is done from an oblique intercostal approach. Within the liver, the branches of the hepatic artery follow their attendant portal veins and are visible well into the periphery if the color Doppler technique is optimized. The hepatic artery can be distinguished from the adjacent vein by its pulsatility, higher velocity (often displayed in a different shade of color), and smaller size. Spectral analysis allows absolute distinction between artery and vein and will confirm patency of the hepatic artery.

The hepatic artery plays a role subordinate to that of the portal vein in parenchymal oxygenation. The portal vein supplies 70–75% of incoming blood [3]. This dual blood supply makes hepatic infarction rare in the native liver. The oxygen content of portal venous blood is usually sufficient to allow normal hepatic function even in the event of complete hepatic artery thrombosis. Abnormalities of the hepatic arteries are rarely a cause of liver disease. Enlargement of the hepatic artery, increased flow, and a tortuous "corkscrew" appearance are commonly observed in patients with cirrhosis and portal hypertension [4], but increased vascular resistance (as shown by an increased resistive or pulsatility index) has not been a useful diagnostic indicator. Because of increased dependence on the arterial system for oxygenation when portal hypertension occurs, the hepatic artery may be detected with color Doppler imaging more easily than the portal vein is. This situation can be particularly troublesome in potential liver transplant recipients in whom the patency of the portal vein must be established. In addition, with real-time sonography, ectatic hepatic arteries in patients with cirrhosis may be difficult to distinguish from dilated intrahepatic biliary radicles [5]. This problem is easily solved by using color or duplex Doppler imaging, as bile ducts produce no Doppler signal [6] (Fig. 1). The differentiation between vascular structures and dilated bile ducts may also be of value when drainage of an obstructive biliary system is considered as a possible treatment. Color Doppler imaging can be used to direct the needle to a dilated duct and avoid puncture of the adjacent vessel.

Color Doppler imaging has been used to investigate arterial flow patterns in and around hepatic masses in an effort to improve the specificity of the sonographic examination. The flow of hemangiomas reportedly is too slow to produce a Doppler shift, and therefore they typically appear avascular. Unfortunately, metastases may also be avascular, and the two cannot be differentiated [7]. Taylor et al. [7] have reported peak systolic Doppler shifts greater than 5 kHz as being specific to hepatocellular carcinoma (HCC). Tanaka et al. [8], who used color Doppler imaging, suggested a "basket pattern" was also typical of HCC. Marn et al. [9], however, reported high-velocity flow in cirrhotic livers without hepatomas and attributed such flow patterns to the presence of small arteriovenous malformations rather than to tumor. Recent work suggests that color Doppler patterns are probably of little value in differentiating various hepatic lesions. Ralls [10] has shown that hemangiomas may have internal vascularity (probably the result of improvements in Doppler sensitivity) and that the patterns described by Tanaka et al. [8] as specific for HCC are commonly seen in metastases. Although of minimal value as a diagnostic tool in hepatic masses, color Doppler imaging can be used to localize areas of significant vascularity if concern exists about the optimum site for biopsy.

The splenic and hepatic arteries are the most common sites for pseudoaneurysms in the abdominal vessels. These abnormalities typically occur in association with trauma or pancreatitis and may appear as a complex or cystic mass on routine real-time examination [11]. When large, pseudoaneurysms may mimic an abscess and percutaneous puncture or drainage may be considered. In order to avoid potential catastrophe, color or duplex imaging should be performed whenever a pseudoaneurysm is even remotely considered as part of the differential diagnosis. Unless a pseudoaneurysm is thrombosed completely, the Doppler characteristics are sufficiently specific that a definitive diagnosis can be made.

The Portal Venous System

The portal vein and its major branches can be easily visualized in all patients by using a right longitudinal intercostal approach similar to that used to display the common hepatic duct. When this approach is used, normal flow in the main portal vein is invariably directed toward the transducer and displayed in red (assuming a red toward and blue away color scheme). Flow in the posterior branch of the right portal vein, however, is away from the transducer and should not be confused with that of the nearby hepatic veins (also typically displayed in blue). If a question exists, the vessel can be followed to its origin or evaluated with spectral Doppler imaging.

Many significant abnormalities of the portal venous system are readily characterized by using duplex and color Doppler imaging. Anatomic abnormalities are relatively unusual, but duplication, an anomalous course, and aneurysms have been described [12, 13] (Fig. 2). In addition, fistulas may affect the portal venous system and involve either the hepatic artery or the hepatic veins. In both cases, fistulous lesions may be congenital or acquired. Communications between the hepatic

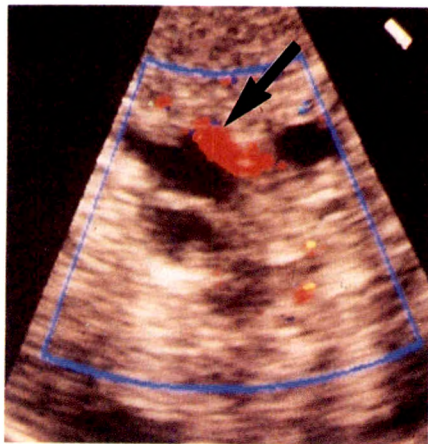


Fig. 1.—Biliary dilatation. Real-time scanning showed numerous parallel, tubular anechoic structures in liver. Early biliary dilatation was suspected, but enlarged hepatic arteries in this patient with cirrhosis were also a consideration. Color Doppler image through one of these areas shows no flow in one tubular structure, confirming biliary dilatation. Note obvious flow in adjacent portal vein (arrow). Color Doppler imaging allows definitive differentiation between dilated ducts and adjacent vessels.

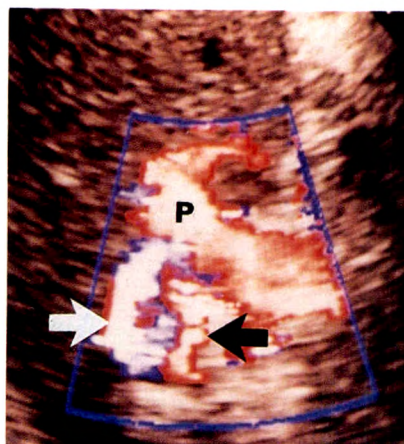


Fig. 2.—Sagittal color Doppler image of a patient with end-stage liver disease and documented portal hypertension shows a portal vein aneurysm (arrows) extending off posterior main portal vein (P). "To-and-fro" flow pattern is similar to that seen in pseudoaneurysms and indicates a vascular cul-de-sac.

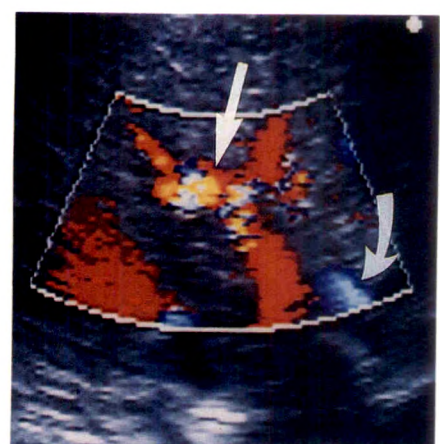


Fig. 3.—Hepatic artery/portal vein fistula in a patient with known fistula and multiple previous hepatic artery embolizations. At time of imaging, patient had recurrence of portal hypertension. Transverse color Doppler image through porta hepatis shows area of high-velocity, turbulent flow (straight arrow) in an artery lying posterior to portal vein. Note reversal of flow in portal vein (curved arrow). Superior mesenteric arteriogram confirmed presence of hepatic artery/portal vein fistula arising from collaterals originating from gastroduodenal artery.

artery and the portal vein tend to be symptomatic; because of the high pressure in the artery, large quantities of blood can be delivered to the portal system, causing severe portal hypertension. Most hepatic vein/portal vein fistulas, on the other hand, are asymptomatic unless they are large enough to divert the majority of portal flow and cause hepatic ischemia. Patients with this type of fistula occasionally have encephalopathy or hypoglycemia [14].

Findings on color Doppler imaging should be definitive in both varieties of fistulas. In patients with hepatic artery/portal vein communications, markedly dilated portal venous structures with abundant formation of collaterals are typical [15] (Fig. 3). Portal vein flow is often reversed and arterialized. Turbulent, high-velocity, low-resistance arterial flow with a color Doppler "bruit" (random color assignment outside the region of an actual vessel) may be present [16]. Although a useful diagnostic sign, a color Doppler bruit may obscure the vascular anatomy of the fistula and can be minimized by increasing the velocity scale or wall filter. Portal vein/hepatic vein fistulas tend to be less symptomatic than arterial lesions, as flow proceeds from one low-pressure system to another. Relatively large cystic spaces may be seen in the liver in the area of the communication. Color Doppler imaging can be used to make the diagnosis by detecting flow in these spaces. With color Doppler imaging, it should also be possible to define the attendant vascular connections [14] (Fig. 4).

The portal venous system is an isolated vascular unit with relatively monophasic flow. Spectral analysis will show only minor fluctuations associated with cardiac or respiratory motion. In cases of hepatic vein/portal vein fistulas, the communication between the systemic and portal venous systems

often allows the triphasic spectral pattern of the hepatic veins to be reflected back into the portal vein, producing a pattern of portal vein pulsatility. Such pulsatility is best characterized by using spectral Doppler imaging but may be evident on the color examination because of its alternating red/blue pattern. Occasionally, however, pulsatile flow may be detected in an apparently normal portal vein. Some degree of portal pulsatility is often observed in control subjects (no hepatic abnormalities), but the recent study by Duerinckx et al. [17] showed that a greater than two-thirds change between peak and minimal velocity should be viewed with suspicion. As previously discussed, any anatomic communication between the systemic and portal veins, including surgically created portacaval shunts or hepatic vein/portal vein fistulas, may lead to a pulsatile portal vein. More commonly, however, clinically relevant portal vein pulsatility is associated with right-sided heart failure (increased right atrial pressure) and/or tricuspid regurgitation [17, 18]. In such cases, patients who have no history of heart disease should be referred for a cardiac evaluation that includes a detailed echocardiogram with specific attention to the tricuspid value.

Portal vein thrombosis (PVT) is associated with neoplasia (HCC in particular), hypercoagulable states, use of oral contraceptives, and biliary atresia. Many cases occur with no apparent underlying abnormality. The signs and symptoms of PVT are relatively nonspecific and include the onset or worsening of ascites and abdominal pain or distension. Hepatomegaly is not typical, and alterations in the results of liver function tests are not diagnostic. Color Doppler sonography is useful in the diagnosis of PVT [19]. The high negative predictive value (0.98) suggests that in patients suspected of

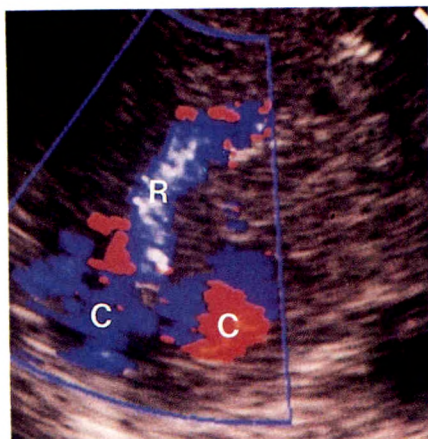


Fig. 4.—Aneurysmal hepatic vein/portal vein fistula in an elderly man with history of colon cancer and percutaneous drainage of right subphrenic abscess. Patient was referred for possible biopsy of several "cystic lesions" in dome of liver. Color Doppler image shows flow in cystic spaces (C) and direct communications with adjacent right hepatic vein (not shown) and posterior branch of right portal vein (R).

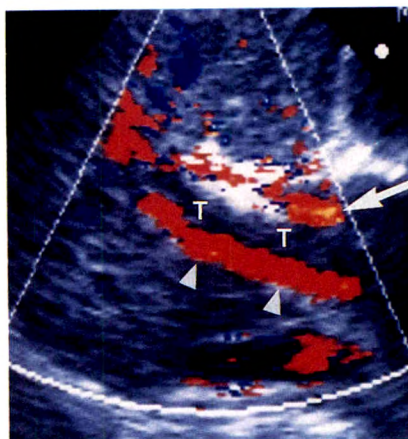


Fig. 5.—Portal vein thrombosis. Color Doppler image shows appropriately directed flow (arrowheads) but hypoechoic thrombus (T) occupying much of vein's lumen. Note hepatic artery (arrow) anteriorly.

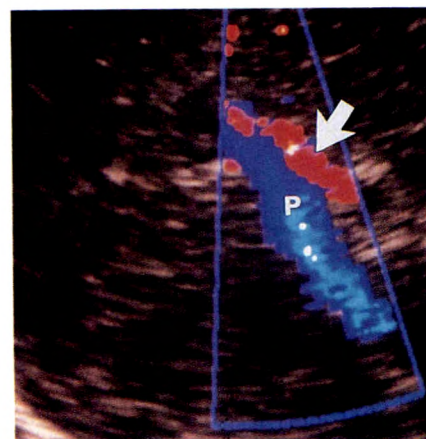


Fig. 6.—Portal hypertension. Color Doppler image through right upper quadrant shows reversed flow in portal vein (P) but appropriately directed flow in adjacent hepatic artery (arrow).

having PVT, normal findings on color Doppler imaging effectively exclude the diagnosis. On the other hand, severe portal hypertension may reduce flow to the point that Doppler signals are not returned. In such cases, the diagnosis of PVT should be suggested, but unless obvious hypoechoic clot is seen within the lumen (Fig. 5), an alternative imaging technique (MR or, preferably, angiography) should be considered for confirmation. Fortunately, such patients are quite unusual in the general population. In one study [19], color Doppler imaging occasionally showed patency of the portal vein that was not visualized on angiography.

In color Doppler imaging of patients with possible PVT, the complexity of the examination should not be underestimated. Machine settings and Doppler angle must be optimized, and scanning should be performed with maximum sensitivity to low flow. High wall-filter settings are particularly effective in eliminating the low-velocity signals of the portal vein and should be minimized. Postprandial scanning should be considered in patients with absent flow, as eating may increase portal vein flow. Suspected thrombosis is best confirmed by using spectral analysis, which should be performed with the patient breathing quietly. The Valsalva effect, which may occur with breath-holding, may eliminate slow flow altogether.

Several sequelae are possible after acute PVT. In some cases, the clot may resolve entirely; in others, fibrosis or calcification within the affected vessel may occur. Eventually, collaterals may fill the porta hepatis and result in cavernous transformation. Sonographically, this entity appears as a racemose collection of vascular structures in the porta hepatis; a single main portal vein is not seen. The real-time features of cavernous transformation should be relatively obvious, and the vascular nature of the structures in the porta hepatis is

easily confirmed by using duplex or color Doppler sonography [20].

The role of color Doppler sonography in the evaluation of portal hypertension remains undefined. Diagnosis with non-invasive techniques is difficult because of the complexity of the vascular dynamics involved and variations in normal velocity associated with such factors as position of the patient, phase of respiration, ingestion of food, or even exercise. Certainly, the ability to acquire directional information makes it possible to make a definitive diagnosis when reversed flow is detected in the portal vein (Fig. 6). Unfortunately, patients with reversal of flow are a relatively small portion of the total number of patients who have the disease. Several studies [21, 22] have evaluated decreases in velocity as an indicator of portal hypertension. Although velocity does decrease in some patients, the normal velocity of the portal vein is extremely variable, and the main collateral pathway largely dictates the flow dynamics in the portal vein. A recanalized umbilical (or paraumbilical) vein, for example, may actually increase flow velocity in the portal vein despite severe parenchymal disease (Fig. 7). The most important contribution of color Doppler imaging in portal hypertension may be better detection and characterization of portal venous collaterals. Color Doppler imaging often shows vessels that are invisible on real-time examinations.

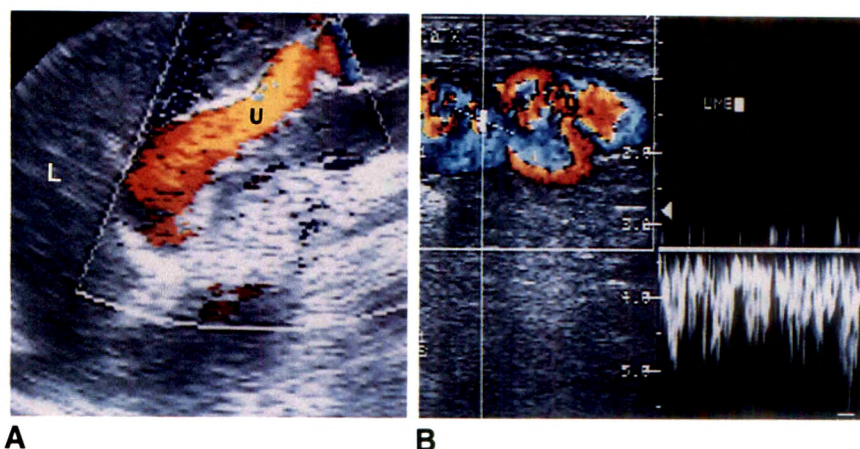
Portosystemic Shunts

The major clinical complications of portal hypertension are ascites and variceal hemorrhage. Although ascites often can be controlled by diuretics, gastrointestinal hemorrhage in patients with portal hypertension remains a major cause of

Fig. 7.—Recanalized umbilical vein.

A, Color Doppler image shows large tubular structure in area of falciform ligament and confirms hepatofugal flow in recanalized umbilical vein (U). Note small, nodular liver (L).

B, High-resolution linear-array color Doppler image obtained by scanning beneath anterior abdominal wall shows typical helical flow pattern of portal vein and its collaterals. Net flow is in one direction, but helical flow is directed both toward and away from transducer. Such patterns can create images with flow above and below baseline when spectral analysis is used alone. Use of color and spectral Doppler imaging facilitates proper placement of Doppler sample volume.



mortality and morbidity. Sclerotherapy is currently used as a palliative measure, but patients with repeated bouts of hemorrhage or intractable ascites may require construction of a portosystemic shunt. Although variations may be encountered, three main types of shunts are used: portacaval, mesocaval, and splenorenal. Placement of a transjugular intrahepatic portosystemic stent between the right or middle hepatic vein and the portal vein is an attractive new option [23] (Fig. 8A). The walls of this type of stent are highly attenuating to the ultrasound beam, but an adequate Doppler imaging study can be obtained in most cases. Historically, the most commonly used shunt has been the end-to-side or side-to-side portacaval shunt. Both types of shunt can be easily imaged by using color Doppler technology (Fig. 8B). Occasionally, in patients who have extremely small, cirrhotic livers or those who have undergone surgical removal of the right hepatic lobe, scanning may be difficult because the usual acoustic window provided by the right lobe of the liver is absent. Portacaval shunts are now used less frequently, as orthotopic liver transplantation has become an accepted form of treatment in patients with end-stage liver disease. An intact portal vein is desirable for transplantation, and any form of disturbance, such as the construction of a portacaval shunt, should be avoided.

Selective portosystemic shunts (mesocaval and splenorenal) are considered advantageous because they do not divert all blood from the portal vein and potentially worsen hepatic encephalopathy. A mesocaval shunt is typically an H-type synthetic graft between the mid superior mesenteric vein and the inferior vena cava (IVC). These shunts are usually located deep in the mid abdomen and may be difficult to detect because of overlying bowel gas and mesentery. Reports of the use of color Doppler sonography in patients who have these shunts, however, show that persistence yields good results [24]. The examination should begin with real-time scanning in an effort to detect the characteristic serrated walls of the Gortex graft. Duplex or color Doppler imaging can be used to confirm flow (Fig. 8C). Alternatively, color Doppler imaging can be used to follow the IVC either proximally or distally until flow enters from a large vessel below the level of the renal veins, which is presumptive evidence that the junction between the graft and the IVC has been

found and that the shunt is patent. Gentle pressure with the transducer will often displace bowel gas and allow at least a portion of the graft walls to be detected. Detection of flow in any portion of a synthetic mesocaval graft is sufficient to confirm patency. In those unusual patients in whom the shunt cannot be detected with certainty, detection of flow reversal in the proximal superior mesenteric vein can be taken as presumptive evidence of patency.

Distal splenorenal or Warren shunts are a third alternative, in which the distal splenic vein is severed and anastomosed to the left renal vein. Portal hypertension is reduced by diverting splenic blood flow; oxygenated blood from the bowel continues to reach the liver. Splenorenal shunts are often the most difficult to image sonographically. The anastomosis usually lies deep in the left upper quadrant, and the walls of this vein-to-vein graft are invisible sonographically. In a study by Foley et al. [25], duplex sonography was unacceptable in evaluation of the patency of splenorenal shunts, and a more recent study [24] corroborated these results. However, the latter study [24] showed color Doppler imaging was quite successful in the evaluation of distal splenorenal shunts [24]. The limbs of these shunts typically lie perpendicular to each other, and Doppler signals are optimally received from two different directions. The splenic limb is often best imaged from an anterior approach, as the vessel is typically oriented vertically. The renal vein, on the other hand, runs in a horizontal plane, and reception of Doppler signals is optimized by scanning from the left flank. The anastomosis itself may be difficult to define in one plane, but its detection is not essential to define patency. Detection of appropriately directed flow in well-defined splenic and renal limbs can be used to imply patency (Fig. 9A). When the shunt is occluded, the thrombus itself is difficult to define. Detection of multiple collaterals in the left upper quadrant instead of singular, well-defined splenic and renal limbs should suggest thrombosis or at least physiologic compromise (possible narrowing of the proximal left renal vein). Further studies are then warranted (Fig. 9B).

The Hepatic Veins

The hepatic veins are anatomically separate from the portal venous system and are normally the sole route of egress of

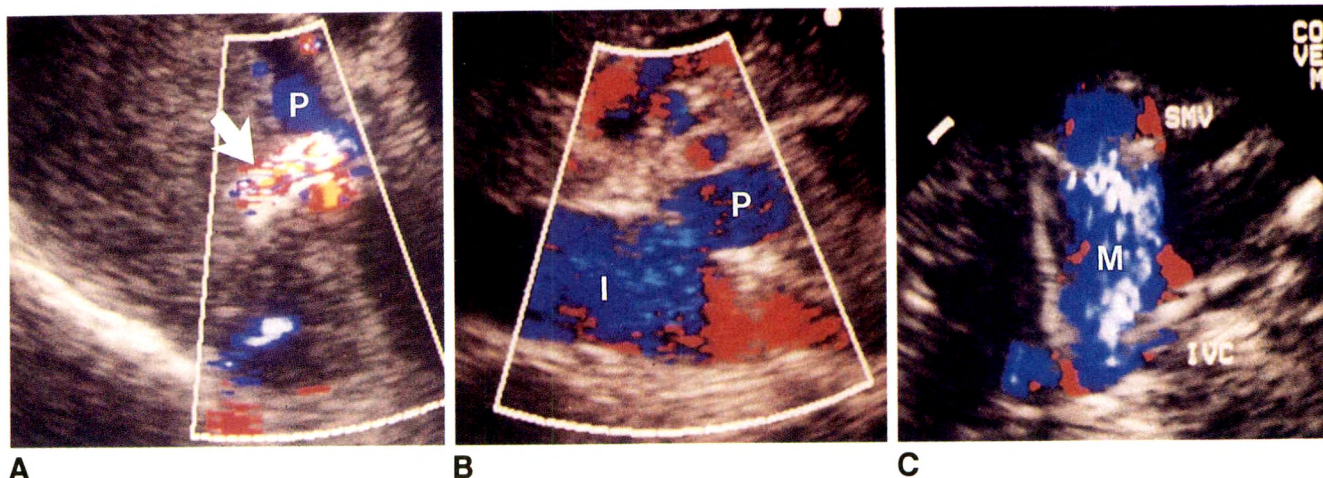


Fig. 8.—Portosystemic shunts.

A, Color Doppler image shows transjugular intrahepatic portosystemic shunt (arrow) is patent. Note reversal of flow in upper portal vein (P). Metallic stent may be highly attenuating to ultrasound beam and make confirmation of flow challenging.
 B, Color Doppler image shows communication between base of portal vein (P) and inferior vena cava (I), confirming patency of portacaval shunt.
 C, Color Doppler image shows flow in mesocaval shunt (M). Note echogenic walls of graft, which connects superior mesenteric vein (SMV) to IVC.

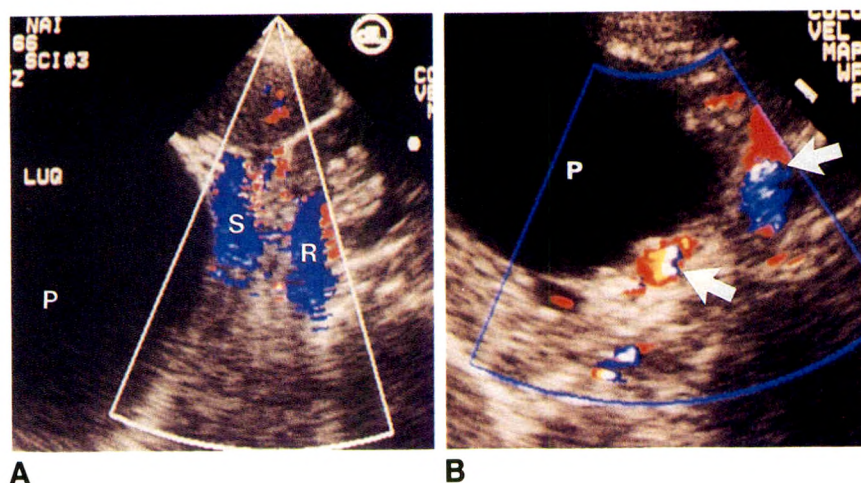


Fig. 9.—Splenorenal shunts.

A, Color Doppler image of patient with suspected thrombosis of splenorenal shunt shows large pancreatic pseudocyst (P). Note well-defined, patent splenic (S) and renal (R) limbs. Although anastomosis was not specifically imaged, well-defined limbs with appropriately directed flow allowed presumptive diagnosis of patency. Sonographic findings were confirmed with angiography.
 B, Color Doppler image of another patient with splenorenal shunt and pancreatitis shows a pancreatic pseudocyst (P). Spleen was enlarged and numerous collaterals (arrows) in left upper quadrant were detected. Shunt thrombosis was confirmed with celiac artery arteriogram.

blood from the liver. There are usually three main hepatic veins (left, middle, and right), although many patients have an accessory or inferior right hepatic vein [26]. Centrally, the hepatic veins join the IVC immediately inferior to the diaphragm and are in open communication with the right side of the heart. Pulsations from the right atrium are reflected back in a complex, triphasic flow pattern found in all central systemic veins. The hepatic veins have two periods of forward flow within each cardiac cycle, corresponding to the two phases of right atrial filling. Contraction of the right side of the heart produces a period of normal, transient flow reversal.

Unlike the portal circulation, in which a variety of pathologic processes may be found, abnormalities affecting the hepatic veins are almost always associated with some form of obstruction, which results in Budd-Chiari syndrome. The signs and symptoms include hepatomegaly, ascites, and upper abdominal pain. Factors associated with Budd-Chiari syndrome are hypercoagulable states (polycythemia rubra vera and paroxysmal nocturnal hemoglobinuria), neoplasia (HCC

and renal and adrenal carcinomas), use of oral contraceptives, trauma, pregnancy, collagen-vascular disorders, and vascular webs. In two thirds of cases, no underlying cause is found [27, 28].

Compromise of hepatic venous outflow can be caused by a lesion located anywhere between the IVC and the hepatic venules, and, as signs and symptoms are not specific, an adequate method for both screening and characterizing the blockage would be desirable. Preliminary experience with color Doppler imaging [29] has been quite encouraging, and suggests that this technique can serve as the initial radiologic examination in any patient suspected of having Budd-Chiari syndrome.

Several investigators [30, 31] have studied the use of real-time and duplex sonography in the diagnosis of Budd-Chiari syndrome. Hepatomegaly and cirrhosis, however, often compress the hepatic veins and make them invisible on real-time sonography. In such cases, duplex sonography cannot be used to evaluate these vessels. The value of duplex sonog-

raphy in the diagnosis of Budd-Chiari syndrome is further decreased by the propensity for pulsations from the left side of the heart to be transmitted throughout much of the left lobe of the liver, such that Doppler signals can be obtained almost anywhere in the parenchyma. These problems are decreased with color Doppler imaging, and compressed but patent hepatic veins often can be visualized even when the veins are not clearly seen on real-time sonography. The anatomic display of color Doppler imaging also allows differentiation of the vessel from the background artifact caused by cardiac motion. Although imaging of the hepatic veins is more difficult in patients with severely shrunken, cirrhotic livers, acute Budd-Chiari syndrome is quite unusual in such patients. Conversely, patients with cirrhosis associated with long-standing Budd-Chiari syndrome should have specific and readily detectable abnormalities.

In the acute phase, Budd-Chiari syndrome is diagnosed when flow in the hepatic veins cannot be detected by using color Doppler imaging. Depending on the cause, actual thrombus may or may not be seen with real-time sonography. Three hepatic veins must be detected in order to exclude the diagnosis, because segmental involvement may occur. The veins of the caudate lobe drain directly into the IVC and are frequently spared when the other hepatic veins are compromised. A large, patent caudate vein should not be confused with a patent middle hepatic vein. In patients with acute hepatic vein thrombosis who are having thrombolytic therapy, color Doppler imaging is useful for monitoring the effect of treatment. Color Doppler imaging has also been used to guide angioplasty and in follow-up studies of patients with IVC webs [32].

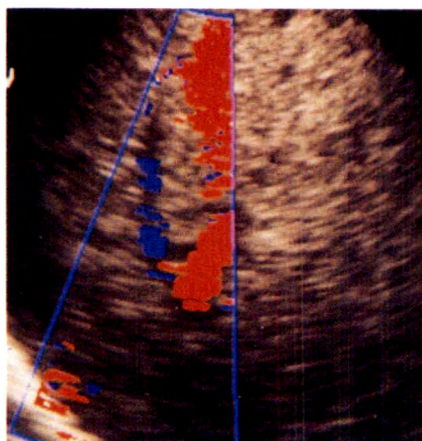
After an acute thrombotic episode, or in patients with long-standing obstruction associated with a web or extrinsic mass, collateral pathways develop. Many of these pathways are unique to Budd-Chiari syndrome and provide definitive features for diagnosis based on color Doppler imaging [29]. A "bicolored" hepatic vein is pathognomonic and indicates a proximal blockage. In this situation, two adjacent branches of a hepatic vein are assigned different colors. Flow is normally directed toward the diaphragm in one and reversed and directed toward the periphery of the liver in the other (Fig.

10). Any intrahepatic collateral (except for a recanalized umbilical vein) should suggest Budd-Chiari syndrome; portal hypertension, on the other hand, almost invariably diverts blood around but not through the liver. In patients with evidence of Budd-Chiari syndrome, the portal vein should be evaluated for concurrent thrombosis, which occurs in about 20% of patients [28].

A unique group of patients with a propensity for venous outflow obstruction are those who have undergone bone marrow transplantation. In this population, conditioning regimens (chemotherapy and radiation) cause an inflammatory reaction that leads to nonthrombotic obliteration of the hepatic venules. Although obstruction is at the microscopic level, signs and symptoms of Budd-Chiari syndrome are similar to those caused by macroscopic obstruction. This phenomenon is specifically termed hepatic venoocclusive disease. The diagnosis of hepatic venoocclusive disease is difficult to establish with radiologic methods, because the main, central hepatic veins remain patent and appear normal with most imaging techniques; transvenous biopsy may be necessary. In a recent study, Brown et al. [33], however, found color Doppler imaging useful in detecting hepatic venoocclusive disease because portal vein flow may be reversed. Although this feature is present in a minority of patients with the disease, it is, nonetheless, sufficiently specific to eliminate the need for further evaluation. A decrease in portal vein velocity is also suggestive of venous occlusion. Unfortunately, portal vein velocities are normally so variable that a baseline scan would have to be available before a true reduction in flow could be determined. For this reason, it has been suggested that all patients have duplex sonography of the portal vein before they begin conditioning for bone marrow transplantation [33]. Contrary to the work of Brown et al. [33], the recent study of Hommeyer et al. [34] found no correlation between sonographic abnormalities (when real-time and color Doppler imaging were used) and venoocclusive disease. Further investigations are necessary to define the role of Doppler imaging in this unusual entity.

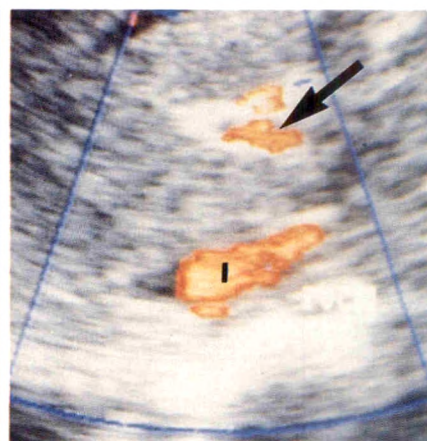
In patients with Budd-Chiari syndrome, conversion of the portal vein to an outflow tract by construction of a portacaval shunt can adequately reduce hepatic congestion and actually

Fig. 10.—Intrahepatic collaterals in Budd-Chiari syndrome. Color Doppler image shows classic bicolored hepatic vein in a patient with chronic Budd-Chiari syndrome. Note appropriately directed flow in superior hepatic vein branch (shown in blue) and reversed flow (shown in red) in other branch.



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Fig. 11.—Budd-Chiari syndrome. Color Doppler image shows inferior vena cava (I) is occluded. Flow is reversed and shown in red. Portal vein (arrow) is patent, but flow is hepatopetal, suggesting occlusion of mesoatrial shunt. Occlusion of proximal IVC and patient's mesoatrial shunt were confirmed with angiography. Occluded shunt is consistent with hepatopetal flow in portal vein.



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halt the progression of parenchymal damage. Unfortunately, compromise of the IVC is often present in Budd-Chiari syndrome and may result from either a primary (extension of thrombus or neoplasm from IVC, congenital web) or a secondary (extrinsic compression from an enlarged caudate or hepatic mass) process (Fig. 11). Evaluation of the IVC is, therefore, essential in patients who are being considered for surgical decompression. Caval compromise precludes the simple decompression of the portal vein via the IVC and necessitates the construction of the far more complex mesoatrial shunt. In these shunts, a synthetic (Gortex) interposition graft diverts blood from the mid superior mesenteric vein to the right atrium [35]. PVT makes construction of either a portacaval or mesoatrial shunt impossible. Mesoatrial shunts have a high propensity for thrombosis and may require frequent imaging. Reported experience with color and duplex Doppler imaging of these shunts has been excellent [23, 29]. Patency can be implied when reversed flow is detected in the portal vein, but the shunt itself is usually easily visualized directly beneath the skin in the right upper quadrant. As with mesocaval grafts, appropriately directed flow in any part of the mesoatrial shunt implies patency. Scans of the shunt obtained within several days of surgical implantation may not be diagnostic, as air within the walls can produce posterior acoustic shadowing and obscure the Doppler image.

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MR Imaging of the Lungs: Value of Short TE Spin-Echo Pulse Sequences

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OBJECTIVE. An experimental short echo delay (TE = 7 msec) T1-weighted spin-echo sequence was compared with a conventional (TE = 20 msec) T1-weighted spin-echo sequence in the assessment of normal and abnormal lung parenchyma. Comparison was also made with high-resolution CT of abnormal lung parenchyma.

SUBJECTS AND METHODS. At 1.5 T, an experimental short echo delay T1-weighted multislice spin-echo sequence (TR = RR interval, TE = 7 msec) was compared with an optimal conventional T1-weighted spin-echo sequence (TR = RR interval, TE = 20 msec, spatial presaturation). Ten healthy volunteers were examined with both sequences. The mean signal intensity and signal-to-noise ratios were calculated in lung parenchyma for both sequences. Two radiologists compared the visualization of normal lung parenchymal structures with the two techniques. In 24 patients with diffuse lung disease, results with both MR sequences and with high-resolution CT were compared.

RESULTS. The signal intensity was significantly greater ($p < .001$) with the TE of 7 msec than with the TE of 20 msec, resulting in a 3.5-fold improvement in the signal-to-noise ratio. The 7-msec TE improved visualization of lung parenchymal structures, including peripheral vessels, interlobular septa or veins, and centrilobular arteries. In the patients with diffuse lung disease, pulmonary parenchymal abnormalities were better visualized on the images with TEs of 7 msec than on images with TEs of 20 msec. When compared with high-resolution CT, the sequence with a TE of 7 msec provided comparable assessment of air-space opacification and dense consolidation, but it was inferior to high-resolution CT in the anatomic assessment of lung parenchyma.

CONCLUSION. This experimental spin-echo sequence with a TE of 7 msec significantly improves the signal-to-noise ratio, allowing improved visualization of normal and abnormal pulmonary parenchyma when compared with conventional spin-echo images with a TE of 20 msec. Although anatomic detail remains inferior to that seen with high-resolution CT, the improved image quality with a TE of 7 msec suggests that assessment and follow-up of parenchymal lung disease might be possible with MR, thereby avoiding ionizing radiation.

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The evaluation of lung parenchyma with MR imaging has been limited by the low signal intensity caused by the low proton density and the short T2 and T2* of inflated lung [1-4]. As a result, minimal signal remains after the echo delay (TE) with conventional gradient-echo (TE = 15 msec) or spin-echo (TE = 20 msec) sequences on current large-bore scanners. Previous studies with a small-bore animal imager [5] have shown increased lung parenchymal signal with very short TE spin-echo sequences.

In human subjects it has been shown that the lung parenchymal signal intensity can be increased by using an ultrashort TE gradient-echo sequence [6]. As a result of the very short gradient-echo delay, this sequence requires use of a projection reconstruction algorithm to calculate the image, instead of the more commonly used two-dimensional Fourier transform. The projection reconstruction algorithm can be augmented with image deblurring techniques to compensate for the

distorted magnetic environment of the lung [7].

We have developed a cardiac-gated T1-weighted spin-echo sequence with a short TE (7 msec) that increases the signal acquired from lung and improves visualization of peripheral vessels and lung parenchyma. This imaging sequence uses the standard two-dimensional Fourier transform reconstruction and has been implemented on a 1.5-T scanner with minimal modifications. We assessed this new sequence in 10 healthy volunteers and in 24 patients with various pulmonary parenchymal abnormalities.

Subjects and Methods

Ten healthy volunteers (mean age, 35 years; range, 28–47 years) were imaged with a 1.5-T imager (Signa, 3.3.9 software release, General Electric Medical Systems, Milwaukee, WI). Three imaging sequences were performed in all subjects. First, a coronal cardiac-gated T1-weighted localizer scan was obtained (TR = RR interval, TE = 20 msec) with one excitation per view. This was followed by a transverse cardiac-gated T1-weighted conventional spin-echo sequence (TR = RR interval, TE = 20 msec) with spatial presaturation above and below the region imaged. Neither flow nor respiratory compensation was used. Sections 5 mm thick with 5-mm gaps were obtained in a caudad to craniad direction [8] by using a 36-cm field of view and four averages. The phase-encoding direction was anterior to posterior. In our experience, this sequence provided optimal T1-weighted images with minimal cardiac motion artifact.

The third imaging sequence consisted of the experimental short echo delay, transverse cardiac-gated T1-weighted spin-echo sequence (TR = RR interval, TE = 7 msec). This sequence used a slice-selective 90° pulse (2.4 msec) truncated at the first zero crossing after the peak and a slice-selective 180° pulse (1.6 msec). A single slice-select refocus gradient lobe was located after the 180° pulse, and all slice-select and read gradient ramp-up and ramp-down times were 0.25 msec. The echo was acquired asymmetrically with the echo peak centered 25% into the readout window. The readout window was narrowed to 6.35 msec. The image bandwidth was ± 20.2 kHz and the low-pass filter bandwidth was ± 16 kHz, resulting in attenuation of image signal intensity at the edges of the field of view in the frequency-encoding direction. However, this region of signal attenuation did not impinge on either hemithorax in any volunteer. The data were reconstructed with a standard two-dimensional Fourier transform without correction for the echo asymmetry. Spatial presaturation, flow compensation, and respiratory compensation were not used. Sections of the same thickness and gap were obtained at identical locations as used for the series with the 20-msec TE, prescribed caudad to craniad, with a 36-cm field of view and four averages. The heart rates of the subjects ranged from 53 to 87 beats per minute (TR = 690–1132 msec).

To monitor RF power deposition, oral temperatures were taken with the subject on the scanner table before the imaging session, after the scan with TE = 20 msec, and after the scan with TE = 7 msec. The images with TEs of 20 and 7 msec were photographed at similar window widths and levels, which were appropriate for visualization of the lung parenchyma. The section thickness for both the 20- and 7-msec TE sequences were verified to be the same by using an axial-slice-thickness analysis phantom (GE model 46-287379G1).

Lung parenchymal signal intensity was measured on the scans with TEs of 20 and 7 msec in the right lung at the level of the bronchus intermedius. A circular region of interest (mean area, 1.8 cm²; SD, 0.3 cm²) was placed at six locations along an arc in the middle third of the right lung on both images. These regions were chosen to sample lung parenchyma, avoiding visible vessels and

bronchi. The mean signal intensity and standard deviation from each region were recorded. A larger circular region of interest (mean area, 25.1 cm²; SD, 2.9 cm²) was measured in air anterior to the right chest wall. All signal intensities were corrected for the 1024 offset present in the scanner image data. The difference in signal intensity between the 20- and 7-msec TE techniques was then calculated for each region sampled in the 10 subjects. The signal-to-noise ratio was calculated for both sequences by using the mean signal obtained in the mid lung (region 4) and the standard deviation from the air over the right side of the chest (region 7). Correction was made for the Rayleigh distribution of noise in the air by multiplying the standard deviation in air by 1.53 [9]. Statistical analysis was performed by using Student's *t* test.

The 20- and 7-msec TE scans of the 10 healthy volunteers were interpreted by two chest radiologists who did not know the technical factors used. The images were assessed for visualization of central and peripheral vessels; lobar, segmental and subsegmental bronchi; interlobular septa or veins; and centrilobular arterioles. The observers noted the sequences in which these structures were visualized and which sequence provided the best visualization. In addition, the observers recorded the relative severity of cardiac and respiratory motion artifacts with the two techniques.

Twenty-four patients with lung parenchymal abnormalities, including idiopathic pulmonary fibrosis (four); sarcoidosis, cystic fibrosis, pulmonary hemorrhage, and extrinsic lipid pneumonia (two each); asbestosis, talcosis, emphysema, silicosis with progressive massive fibrosis, and Churg-Strauss syndrome (one each); single-lung transplant (five); and double-lung transplant and heart-double lung transplants (one each), were imaged with the 20- and 7-msec TE sequences. The parenchymal abnormalities in the native lung of the single-lung transplants included panacinar emphysema due to α_1 -antitrypsin deficiency (four) and severe pulmonary arterial hypertension as a result of portal-systemic shunting (one). The double-lung transplant was performed for cystic fibrosis and the heart-double lung transplant for congenital heart disease and resultant pulmonary arterial hypertension. Five of the transplanted lungs showed no evidence of rejection and two showed grade 3 or 4 rejection. The scans were interpreted without knowledge of technical factors used and diagnostic preference recorded.

In all 24 patients, high-resolution CT (HRCT) scans (1.5-mm collimation, high-spatial-frequency reconstruction algorithm) at 10-mm intervals through the chest also were obtained. Comparison was made with the MR images for visualization of diffuse air-space opacification, dense consolidation, and normal and abnormal pulmonary parenchymal structures.

Results

In all six lung parenchymal regions measured, the sequence with a TE of 7 msec yielded significantly increased signal intensity ($p < .001$) when compared with the sequence with a TE of 20 msec (Table 1). As a result, the signal-to-noise ratio on the images with the 7-msec TE was 3.5 times greater (mean, 5.89; SE, 0.56) than that on the images with the 20-msec TE (mean, 1.70; SE, 0.19; $p < .001$). This increased signal on the image with a TE of 7 msec allowed appreciation of the gradient in lung signal intensity from the most dependent region (region 1) to the most nondependent region (region 6) in all healthy subjects (Fig. 1). In contrast, the gradient in lung signal intensity was not visualized on the image with a 20-msec TE, except for increased signal in the most dependent region of the lung.

TABLE 1: Lung Parenchymal Signal Intensity

TE Value	Lung Parenchyma Region						Air (Region 7)
	1	2	3	4	5	6	
7 msec	52	41	36	33	31	29	8
20 msec	22	14	14	13	11	12	9
Signal difference	30	27	22	20	20	17	-1

Note.—Lung parenchymal signal intensity was measured with six circular regions of interest placed at equal intervals from the most dependent to the most anterior aspects of the right lung (regions 1–6, respectively). Air signal intensity was measured with a large circular region of interest located anterior to the right chest wall.

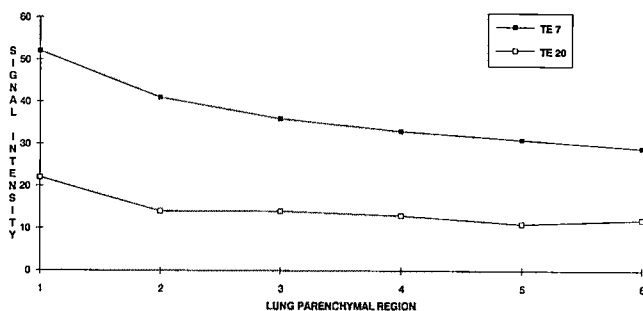


Fig. 1.—Graph comparing signal intensity at each of six locations in right mid lung zone for MR sequences with TEs of 7 (TE 7) and 20 (TE 20) msec in 10 healthy volunteers. A gradient in signal intensity from the most dependent lung region (1) to the most anterior lung region (6) can be seen with TE = 7 msec sequence. However, both absolute signal intensity and gradient in signal intensity are decreased with 20-msec TE sequence.

The increased signal-to-noise ratio also provided visualization of peripheral vessels, interlobular septa or veins, and centrilobular arteries on the image with a 7-msec TE (Fig. 2) throughout the lung (Table 2). In contrast to the sequence with a 20-msec TE, signal arising from aerated lung parenchyma was always greater than the signal from air surrounding the patient on the image with a 7-msec TE. As a result, normal lung could be differentiated from emphysematous lung. Lobar and segmental airways were visible on images with both TEs. However, identification of airways was facilitated on the image with the 7-msec TE because air within the airway was of lower signal intensity than the signal arising from surrounding aerated lung. Subsegmental airways were not seen with either technique. The course and size of central pulmonary vessels were equivalent with both techniques. However, contrast between flowing blood and the vessel walls was greater with the 20-msec TE than with the 7-msec TE. Visualization of chest wall and mediastinal structures was equivalent with both techniques. Respiratory motion artifact was equivalent with the two techniques. The intensity of cardiac motion artifact in the phase-encoding direction was decreased with the TE of 7 msec in comparison with the TE of 20 msec.

In all 24 patients with pulmonary parenchymal abnormalities, visualization of lung parenchymal structures was improved with the TE of 7 msec. In particular, diffuse ground-glass infiltrates were more visible on the image with the 7-msec TE (Fig. 3) and were more easily differentiated from

TABLE 2: Lung Structure Visualization in 10 Healthy Volunteers

Structure(s)	Visualized with TE of:		Best Visualized with TE of:	
	20 msec	7 msec	20 msec	7 msec
Vessels				
Central	10	10	10	0
Peripheral	8	10	0	10
Airways				
Lobar	10	10	0	10
Segmental	10	10	0	10
Secondary pulmonary lobule				
Interlobular septum or vein	7	9	0	9
Centrilobular artery	3	8	0	8

surrounding normal and abnormal lung. In patients with lung transplants, the extent of diffuse infiltrate associated with rejection was better appreciated on the image with a 7-msec TE (Fig. 4) than on the image with a 20-msec TE. In lung transplant patients with no biopsy evidence of rejection, confident identification of normal lung parenchymal structures could be made only on the image with a TE of 7 msec (Fig. 5). Densely infiltrated lung (hemorrhage, inflammation) and extensive fibrosis were visualized equally well with both techniques (Fig. 6). However, partially infiltrated and normal lung adjacent to dense infiltrates was better visualized with the TE of 7 msec.

When MR images with a 7-msec TE were compared with HRCT images, the presence and extent of diffuse air-space opacification and densely infiltrated lung were comparable. While normal pulmonary parenchymal, bronchial, and vascular structures were visualized on the images with 7-msec TEs, they were identified more clearly on the HRCT images.

In comparison with the oral temperature taken before the imaging session, no significant temperature difference was recorded after the scan with a 20-msec TE (0.3°C; standard error, 0.2°C; $p > .10$) nor after the scan with a 7-msec TE (0.09°C; standard error, 0.07°C; $p > .10$).

Discussion

Previous authors have noted that normal adult lung shows no more MR signal than does background air when conventional MR gradient- and spin-echo sequences are used [1]. The lack of signal is due to both the low proton density and the difference in the diamagnetic susceptibility of air and soft

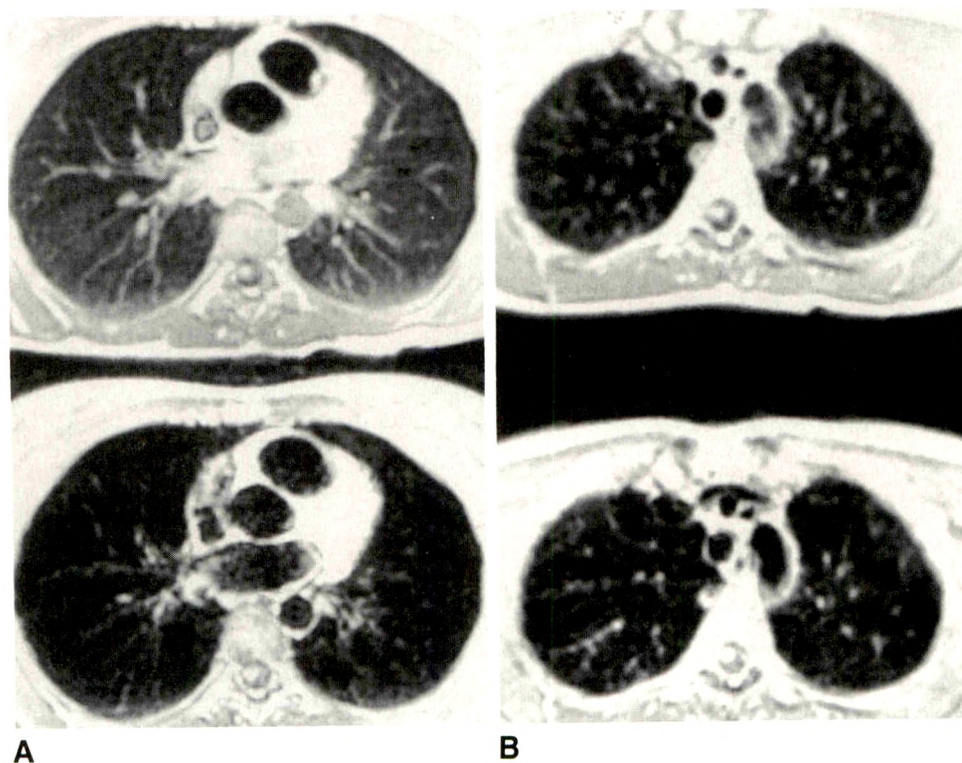


Fig. 2.—Comparison of MR images with TEs of 7 (top) and 20 (bottom) msec photographed at identical windows and levels in a healthy volunteer. A and B, Both lower (A) and upper (B) lung sections show increased signal intensity arising from lung parenchyma with TE = 7 msec. In addition, visualization of peripheral vessels is improved on 7-msec TE image.

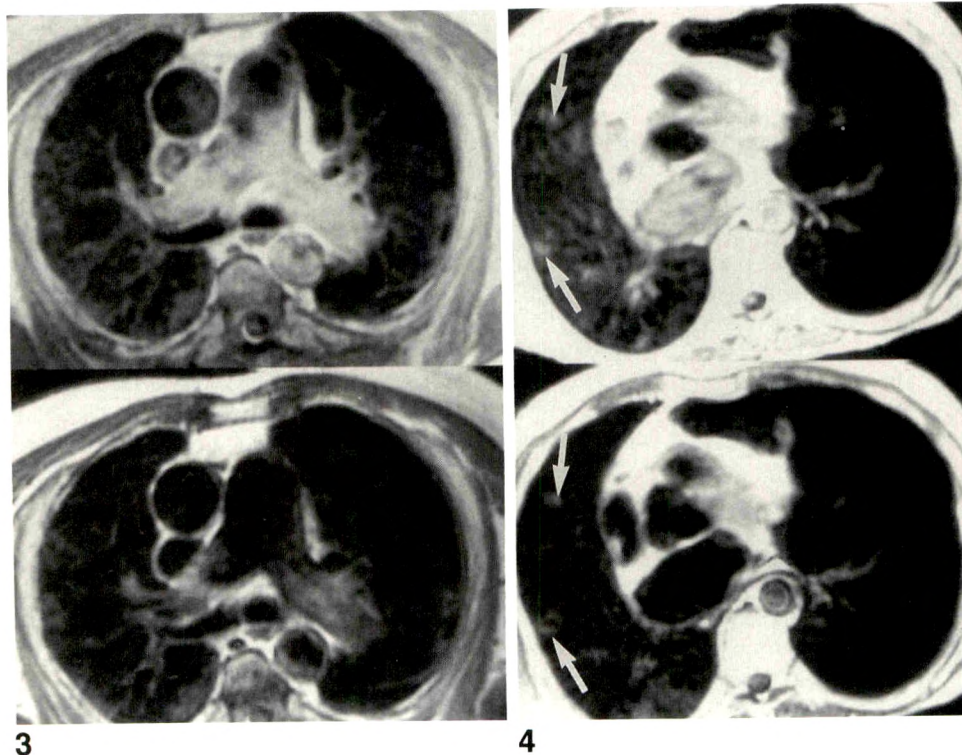


Fig. 3.—Patient with asbestosis and a desquamative interstitial pneumonia reaction. Diffuse ground-glass infiltrates are more easily distinguished from surrounding retractile emphysema on MR image with 7-msec TE (top) than on MR image with 20-msec TE (bottom). Peripheral vessels are more visible with TE of 7 msec because of improved signal-to-noise ratio.

Fig. 4.—MR images with TEs of 7 (top) and 20 (bottom) msec (identical windows and levels) in a patient with a right-sided lung transplant and biopsy-proved grade 3 rejection. Sequence with 7-msec TE provides better visualization of diffuse increase in signal in right lung than does sequence with 20-msec TE. Minimal signal is seen in emphysematous left lung on both sequences. Focal nodules (arrows) seen on both sequences are due to pulmonary hemorrhage from transbronchial biopsy.

tissue in inflated lung, which causes magnetic field gradients at each air-tissue interface [10]. The difference in magnetic susceptibility causes large gradient magnetic fields (up to 9 ppm) [11] in the normally homogeneous main magnetic field

present in modern superconducting MR imagers (0.5 ppm) [12]. In the absence of motion of the water molecules, a spin-echo sequence would completely compensate for the inhomogeneity of the magnetic field in the lung parenchyma.

Fig. 5.—Comparison of MR images with TEs of 7 (top) and 20 (bottom) msec (identical windows and levels) in a patient with a heart-double lung transplant and no evidence of rejection on biopsy. Normal lung parenchymal structures that are not visible on image with 20-msec TE can be identified on image with 7-msec TE.

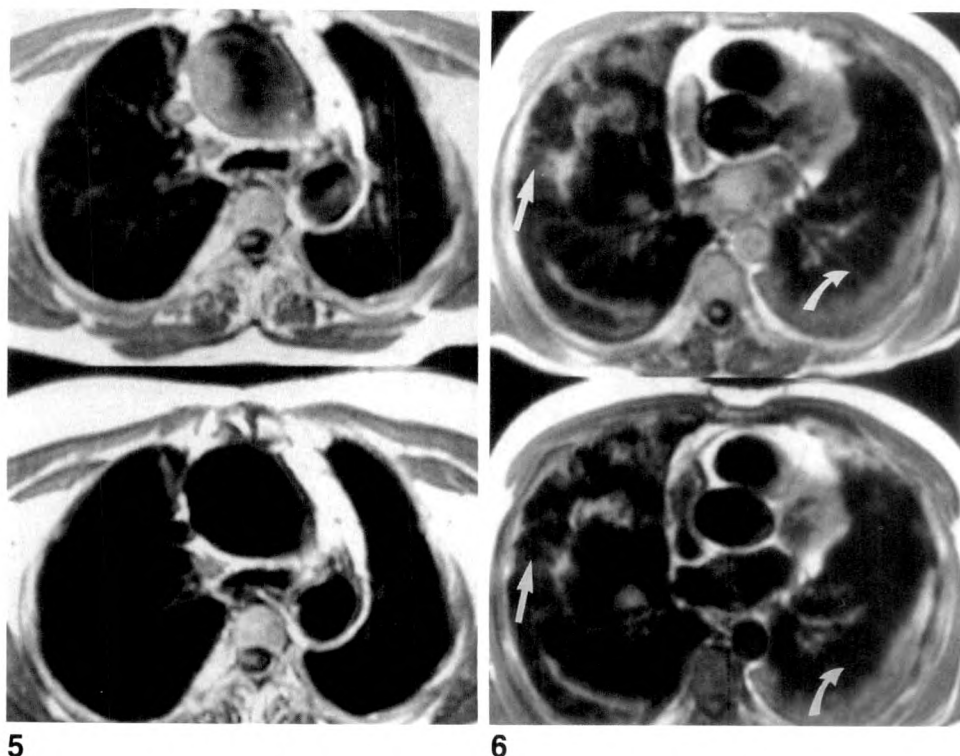


Fig. 6.—MR images with TEs of 7 (top) and 20 (bottom) msec (identical windows and levels) in a patient with biopsy-proved Churg-Strauss syndrome. Airless regions of lung due to dense infiltrate are seen equivalently with both techniques. However, areas of partial infiltration (straight arrows) and vascular structures within normal lung (curved arrows) are better visualized on image with TE of 7 msec.

Motion of the lung water molecules due to diffusion and perfusion causes dephasing that is not recoverable with conventional spin-echo sequences [13]. As a result of the combination of these gradient magnetic fields and motion, the T2 relaxation time of inflated lung is among the shortest in body tissues, and conventional gradient-echo and spin-echo TE times are too long to acquire significant signal. This T2 shortening effect is diminished in lung where the air has been partially or completely displaced by either fluid or soft tissue, accounting for the increased signal that is seen in densely infiltrated lung.

Our results show that a 3.5-fold increase in the signal-to-noise ratio can be obtained with a TE of 7 msec when compared with a conventional 20-msec TE. Because this sequence uses a spin echo, some of the signal dephased by the inherent magnetic field gradients in the lung is refocused and a longer TE than would be possible with a gradient echo can be used. This leaves adequate time in the spin-echo sequence for the phase-encoding step of spin-warp imaging [14], allowing the use of a standard two-dimensional Fourier transform reconstruction. When gated to every R wave, this sequence is relatively T1 weighted. The reduced TE of this sequence also results in a smaller intersequence delay (25 msec) compared with a conventional 20-msec TE (48 msec with spatial presaturation and 37 msec without presaturation), allowing more images to be acquired in a given RR interval. As a result, a larger region of the chest can be imaged in a single acquisition.

The improved signal-to-noise ratio allows normal lung parenchyma to be differentiated from surrounding air and em-

physematous lung. Areas of mild air-space opacification resulting in ground-glass density are more visible. In regions where magnetic susceptibility gradients are not found, such as infiltrated lung and chest wall soft tissues, the 7- and 20-msec TE sequences yield similar image quality. The only disadvantage to the 7-msec TE is the decrease in vascular contrast, which can make it more difficult to differentiate hilar masses from pulmonary vessels. However, this effect most likely contributes to the improved visualization of small peripheral vessels.

Although the 7-msec TE images are superior to the 20-msec TE images in the assessment of the lung parenchyma, they are inferior to HRCT. The superiority of HRCT in the assessment of fine parenchymal detail results from the narrower collimation, the high-spatial-frequency algorithm, and the high contrast between lung parenchyma and surrounding air. The major disadvantage of HRCT is the radiation dose. By comparison, MR assessment of normal parenchyma is compromised by a low signal-to-noise ratio and image degradation due to motion artifacts. However, when normal parenchyma is replaced by inflammatory infiltrate or fluid, the signal-to-noise ratio improves dramatically not only because of the increased proton density but also because the number of air-tissue interfaces decreases and thus image degradation due to magnetic susceptibility effects decreases. As a consequence, the 7-msec TE technique was judged to be comparable to HRCT and superior to the 20-msec TE technique in the assessment of air-space opacification and dense lung infiltration. In agreement with previous studies [15], these results suggest a potential role for spin-echo sequences with

a 7-msec TE in the assessment and follow-up of patients with infiltrative lung disease.

With shortening of the pulse width, the RF power deposition increases. We have calculated that the average specific absorption rate of the 7-msec TE sequence applied in this study was always less than 0.8 W/kg and was approximately equal to the absorption rate of the conventional 20-msec TE sequence with presaturation. Oral temperature measurements were not significantly different for the two sequences. These data indicate that the 7-msec TE sequence has acceptable RF power deposition.

We conclude that significantly increased signal and improved lung parenchymal images can be obtained from aerated normal and abnormal lung by using a spin-echo technique with an echo delay of 7 msec. This sequence is cardiac gated and allows the use of the standard two-dimensional Fourier transform reconstruction. This sequence is easily applied to current commercial MR scanners. Further improvements in image quality should be possible with greater reduction in TE and allowance for the asymmetric echo in the reconstruction algorithm.

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Chronic Hypersensitivity Pneumonitis: Use of CT in Diagnosis

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OBJECTIVE. In its subacute or chronic form, hypersensitivity pneumonitis is often difficult to distinguish clinically and physiologically from other idiopathic diffuse lung diseases. The aim of this study was to identify high-resolution CT features that allow distinction of chronic hypersensitivity pneumonitis from other chronic diffuse parenchymal lung diseases.

MATERIALS AND METHODS. Six patients with chronic hypersensitivity pneumonitis were examined with pulmonary function testing, bronchoalveolar lavage, lung biopsy, chest radiography, and high-resolution CT. The chest radiographs and high-resolution CT scans were reviewed independently by three observers without knowledge of the patients' clinical status. Discrepancies between the observers were resolved by consensus.

RESULTS. The chest radiographs revealed normal lung volumes with a combination of abnormalities: a mixed alveolar/interstitial pattern in five cases, peribronchiolar thickening in three, a diffuse granular pattern in one, and a linear fibrotic pattern in one. In general, the high-resolution CT scans showed more abnormalities than were apparent on the plain chest radiographs. High-resolution CT revealed centrilobular, peribronchiolar, indistinct nodular opacities, of various numbers, in all cases. Four cases had areas of ground-glass density, three cases had lobular areas of hyperlucency, and one case had areas of pulmonary fibrosis and honeycombing.

CONCLUSION. We confirm that high-resolution CT can most clearly show the type and distribution of parenchymal abnormalities in patients with hypersensitivity pneumonitis. Importantly, although not pathognomonic, the high-resolution CT finding of centrilobular, peribronchiolar, indistinct nodules should suggest the diagnosis of chronic hypersensitivity pneumonitis.

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Hypersensitivity pneumonitis is an immunologically mediated disorder characterized by a granulomatous, interstitial, and alveoli-filling process [1, 2]. It is caused by inhalation of specific environmental organic antigens. Manifestations on chest radiographs vary considerably and are not diagnostic or predictive of the clinical stage of the disease. In the acute phase, the chest radiographic findings may be normal or a diffuse ground-glass pattern may be apparent. With time, a fine nodular or reticulonodular pattern may become evident. In chronic or late stages of the disease, honeycombing, retraction of the upper lobes, and development of lung cysts may be seen. Consequently, the radiographic findings are indistinguishable from those of several other chronic diffuse fibrotic lung diseases.

High-resolution CT (HRCT) has been useful in the investigation of many diffuse pulmonary diseases [3-5]. Limited descriptions of the HRCT findings in hypersensitivity pneumonitis have been reported [6-10]. In this study, we describe the HRCT findings in six cases of chronic hypersensitivity pneumonitis in which the clinical, bronchoalveolar lavage, radiographic, and pathologic results were available. The purpose of the study was to identify the HRCT patterns of chronic hypersensitivity pneumonitis and determine whether these may be useful in suggesting

hypersensitivity pneumonitis when diagnosing obscure diffuse lung disease.

Materials and Methods

Study Group

The study population consisted of six patients with hypersensitivity pneumonitis. The diagnosis was established from a compatible exposure history, the presence of suggestive clinical and radiologic findings, the demonstration of serum precipitins to the suspected antigen, and a lung biopsy showing characteristic histologic features [8]. Three were men and three were women, with a mean age of 52 years (range, 37–69 years). All were nonsmokers at the time of diagnosis; four were former smokers who had not smoked for at least 1 year. All of the patients had dyspnea or cough. The duration of symptoms (chronic cough, exertional dyspnea) ranged from 6 to 30 months, with a mean duration of 17 months.

Results of pulmonary function studies were abnormal in all six patients. A restrictive pattern of abnormality was found in three patients. Three patients had an obstructive pattern associated with a marked increase in residual volume consistent with air trapping. The diffusing capacity corrected for alveolar volume was reduced in two subjects. Mild to moderate hypoxemia at rest was found in all patients on the basis of abnormal alveolar-arterial oxygen gradients.

Results of bronchoalveolar lavage were available in five patients. Findings were abnormal in all five patients, with significant alveolitis characterized by a moderate to marked lymphocytosis. One patient also had an increased percentage of neutrophils. These findings are consistent with hypersensitivity pneumonitis.

Lung biopsies were done in all subjects. Two patients underwent open lung biopsy, and four patients had transbronchial biopsy immediately after bronchoalveolar lavage. A combination of histologic findings consistent with the diagnosis of hypersensitivity pneumonitis was seen in all patients. Cellular bronchiolitis, diffuse interstitial infiltrates, and scattered nonnecrotizing granulomas were shown in all, and intraluminal granulation tissue polyps within respiratory bronchioles (bronchiolitis obliterans) were shown in three patients. Frequently, granulomatous macrophage aggregates were present in the adjacent parenchyma. The active interstitial infiltrate varied in intensity. The infiltrates consisted of lymphocytes and plasma cells, with mild to marked thickening of the alveolar interstices. Giant cells, single or in multiple clusters, were commonly identified, and neutrophils and eosinophils were occasionally present.

The exposure leading to hypersensitivity pneumonitis was determined in all subjects. Three patients had bird-breeder's lung. Two were exposed to molds or fungi contaminating the heating/cooling air systems in their homes. One was a chemical worker exposed to isocyanate. All patients were classified as to the chronic clinical stages of the disease. All patients were removed from exposure to the suspected antigen. Four received a course of prednisone treatment.

Radiologic Examination

Standard posteroanterior chest radiographs and CT scans of the lungs were obtained in all patients. The HRCT scans and chest radiographs were obtained between 1 and 12 days before the lung biopsy. All scans were obtained with a General Electric 9800 CT scanner (Milwaukee, WI) by using the HRCT scanning parameters described by Mayo et al. [3]. Five patients were scanned while they were supine during suspended respiration, and the sixth was scanned while prone at maximum inspiration and maximum expiration. Sections 1.5 mm thick were imaged every 10 mm. Two of the patients had repeated modified HRCT (performed at four levels: top of the

aortic arch, level of the tracheal carina, and two scans through the lower lung) 3 months after the initial evaluation and biopsy. The follow-up HRCT scans and chest radiographs were obtained within 24 hr of each other. All HRCT scans were processed with a high-frequency reconstruction algorithm. The HRCT studies and chest radiographs were reviewed independently and without knowledge of the clinical status. When the interpretations were different, the final decision was reached by consensus.

Results

The chest radiographs revealed nonspecific peribronchial thickening in three patients. These three patients also had an obstructive ventilatory defect shown by pulmonary function testing and had histopathologic evidence of bronchiolitis associated with intraluminal polyps (bronchiolitis obliterans). Lung opacities were present in two patients, manifested as a ground-glass pattern in one and a reticulonodular pattern in the other. Both of these patients had a predominant restrictive ventilatory defect, and interstitial infiltrates with poorly defined macrophage aggregates were found on lung biopsy. One subject had no parenchymal abnormalities shown on plain chest radiographs.

On HRCT, all six cases had evidence of small, indistinct, centrilobular nodules throughout the lung parenchyma. These nodules were clearly located in the central portion of the secondary pulmonary lobule and did not extend to the pleural surface. The profusion of these nodules varied considerably. In four cases, areas of ground-glass densities were seen that were consistent with the active alveolitis found on bronchoalveolar lavage and biopsy. Three subjects had lobular areas of hyperlucency within the pulmonary parenchyma. Two of these three had functional evidence of limitation of air flow. Examples of the chest radiographs and HRCT scans for these patients are presented in Figures 1–3.

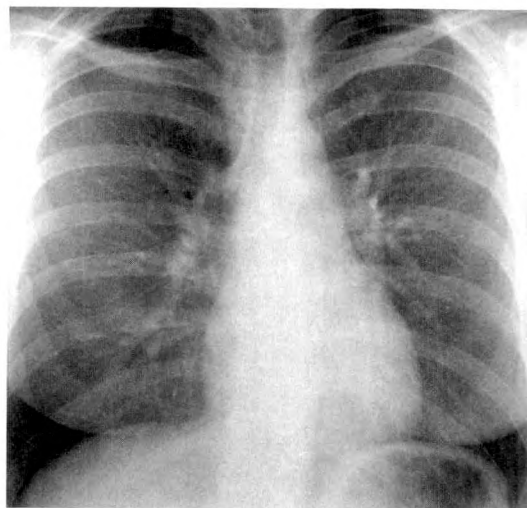
Discussion

Hypersensitivity pneumonitis encompasses a group of diseases in which an immunologic response to an inhaled organic antigen occurs in the lung [1, 2, 11]. Chronic hypersensitivity pneumonitis usually is from low-level, repeated exposures to the antigen. This results in an insidious illness characterized by exertional dyspnea, cough, fatigue, and weight loss. Rales are present on physical examination. The chest radiographs reveal nodular or reticulonodular opacities, sometimes with honeycombing in the late stages. Often the disease is unsuspected because an identifiable exposure is not elicited, and idiopathic interstitial fibrosis or bronchiolitis obliterans is mistakenly diagnosed. Lung biopsy is frequently required for diagnosis [12].

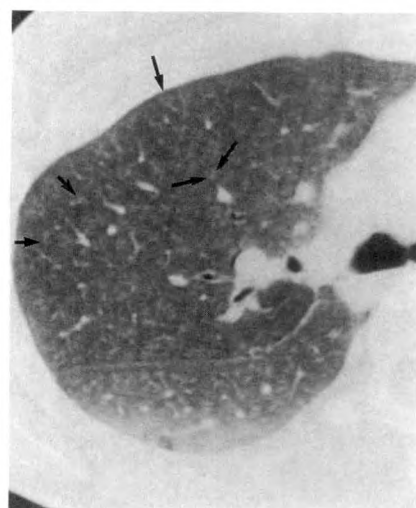
A recent study has suggested that the sensitivity of chest radiographs for detecting hypersensitivity pneumonitis has declined, owing to earlier recognition of the disease with improved immunologic assays [13]. However, in patients with chronic hypersensitivity pneumonitis, the chest radiographic findings are almost always abnormal, usually including a coarse reticular or ground-glass pattern, volume loss, and ring shadows characteristic of honeycomb lung. However,

Fig. 1.—A, Chest radiograph shows a ground-glass pattern of density throughout both lungs.

B, High-resolution CT scan of right upper lobe of lung shows numerous small centrilobular nodules (arrows) and a diffuse ground-glass pattern of density throughout lungs.



A

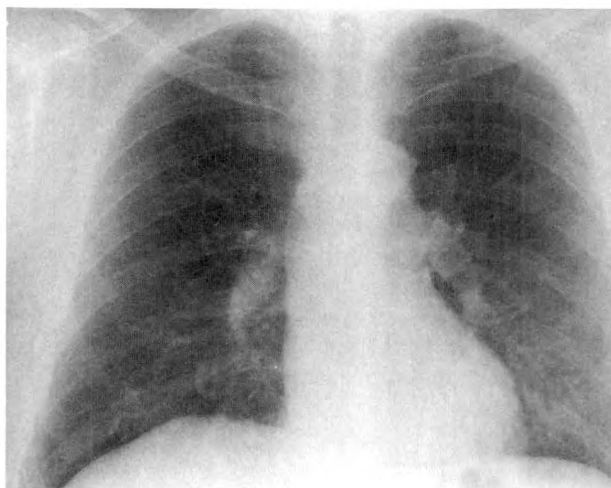


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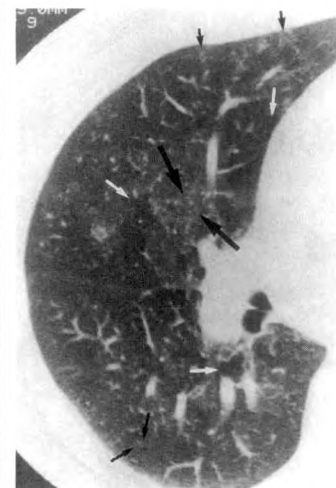
Fig. 2.—Patient with severe symptoms who required hospitalization. Pulmonary function tests showed a severe obstructive ventilatory defect.

A, Chest radiograph shows minimal reticulonodular densities lateral and inferior to right hilum.

B, High-resolution CT scan reveals poorly defined ground-glass densities, some of which correspond to lobules (large black arrows). Centrilobular nodules (small black arrows) and hyperlucent lobules (white arrows) are visible.



A



B

these findings are not specific for hypersensitivity pneumonitis. Few studies have examined the HRCT manifestations of hypersensitivity pneumonitis [6–10]. Even less information is available regarding the HRCT manifestations as they relate to the different stages of the disease. Mathieson et al. [14] were unable to distinguish hypersensitivity pneumonitis from other chronic diffuse infiltrative lung diseases. Bergin and Müller [15] suggested that the distribution of the interstitial lung disease can be useful in differentiating hypersensitivity pneumonitis from other diffuse infiltrative lung diseases. They suggested that the HRCT findings of hypersensitivity pneumonitis were predominantly in the middle interstitial compartment of the lung, that is, around bronchi and vessels. We did not find the distribution in our patients, possibly because we included only patients with chronic disease.

Poorly defined nodules and patchy areas of ground-glass density have been reported in patients with hypersensitivity pneumonitis [7–10, 13]. Silver et al. [6] described the CT findings in 11 cases of hypersensitivity pneumonitis and correlated these with the pathologic manifestations in seven. As

have we, they emphasized a centrilobular distribution for these small, poorly defined nodules in patients with subacute or chronic disease. They also detected a mixed pattern of abnormality, patchy air-space opacification (hazy increased density), and linear fibrosis in the chronic phase. They found that the abnormalities were random without central or peripheral predominance.

When these small centrilobular nodules were seen on CT scans in our cases, polypoid intraluminal granulation tissue within bronchioles (bronchiolitis obliterans) and an active alveolitis filling alveoli around the central area of the lobules were found on lung biopsy. This partial or complete obstruction of the bronchioles may lead to the physiologic derangements found in these patients, namely, air-flow obstruction and air trapping. Bronchial obstruction may also explain the patchy areas of hyperlucency that conformed to a lobular distribution seen on HRCT (Figs. 1B and 3B). Finally, the bronchiolocentric distribution of these lesions probably accounts for the relatively high yield of transbronchial biopsies in establishing the diagnosis of hypersensitivity pneumonitis.

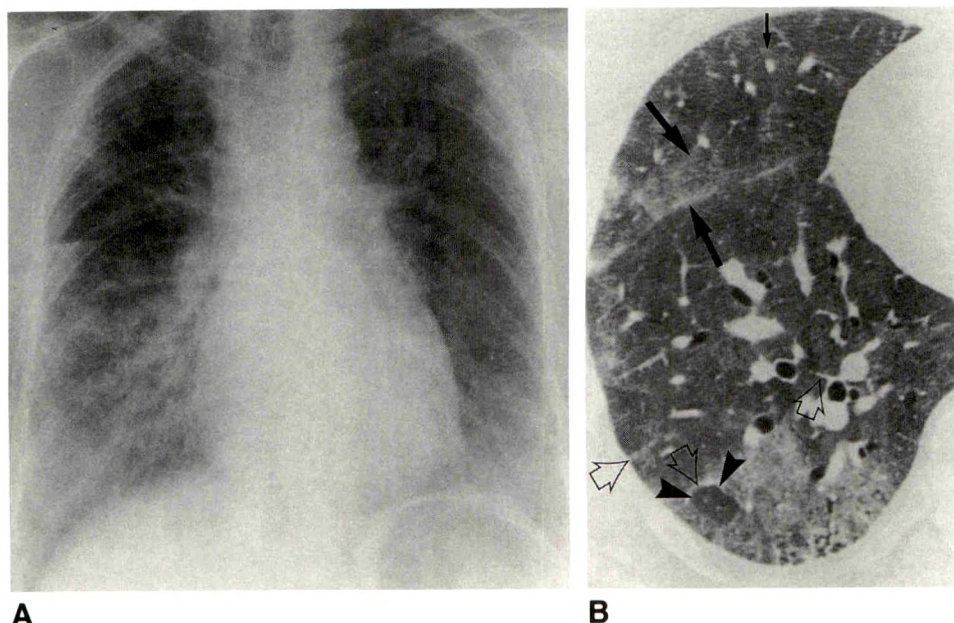


Fig. 3.—Patient with clinically severe disease who had mixed restrictive and obstructive pulmonary function abnormalities and severe hypoxemia at rest. Bronchoalveolar lavage showed active lymphocytic alveolitis, and transbronchial biopsy of right lower lobe revealed an extensive interstitial lymphoplasmacytic infiltrate of moderate to marked cellularity.

A, Chest radiograph reveals a marked increase in lung density, most prominent in right lower zone of lung. Reticulonodular opacities are present, especially in right upper zone of lung and at left base.

B, High-resolution CT scan shows peripheral interlobular septal thickening (open arrows), poorly defined ground-glass opacities (large solid arrows), centrilobular peribronchiolar nodules (small solid arrow), and a hyperlucent lobule (arrowheads). In addition, areas of honeycombing and fibrosis were seen.

Pathologically, an interstitial infiltrate consisting of macrophages, lymphocytes, and plasma cells is frequently seen in hypersensitivity pneumonitis. The HRCT finding of ground-glass densities might be explained by this cellular infiltrate in the alveolar walls. Alternatively, the small granulomas within the alveolar septa could be sufficiently numerous to account for the ground-glass densities. Honeycombing is part of the final stage of lung injury and repair. In the single case of hypersensitivity pneumonitis with honeycomb lung, the distribution of the lesions was similar to that found in idiopathic interstitial fibrosis.

This study suggests that, in patients with obscure chronic lung disease, the appearances on HRCT may have a role in suggesting the diagnosis of hypersensitivity pneumonitis. The frequent finding of centrilobular nodules on HRCT in patients with hypersensitivity pneumonitis has not been emphasized. This centrilobular site contains the airway and pulmonary artery serving the lobule. Thus, lesions arising from either small-airway inflammation or vasculitis would tend to occur at this site. The presence of small centrilobular nodules can also suggest that transbronchial biopsy can successfully supplement bronchoalveolar lavage for diagnosis. Finally, HRCT might provide objective evidence of improvement when patients with chronic hypersensitivity pneumonitis are followed up.

ACKNOWLEDGMENTS

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Malignant Pleural Mesothelioma: Value of CT and MR Imaging in Predicting Resectability

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OBJECTIVE. Our objective was to determine if CT or MR imaging findings could be used to accurately predict resectability in patients with biopsy-proved malignant pleural mesotheliomas.

SUBJECTS AND METHODS. CT and MR findings in 41 consecutive patients with malignant mesotheliomas who were referred to the thoracic surgery clinic for extrapleural pneumonectomy were studied by thoracic radiologists before surgery. Review of radiologic studies focused on local invasion of three separate regions: the diaphragm, chest wall, and mediastinum. Results of all imaging examinations were carefully correlated with intraoperative, gross, and microscopic pathologic findings.

RESULTS. After radiologic and clinical evaluation, 34 patients (83%) had thoracotomy; 24 of these had tumors that were resectable. The sensitivity was high (>90%) for both CT and MR in each region. Specificity, however, was low, probably because of the small number of patients with unresectable tumors.

CONCLUSION. CT and MR provided similar information on resectability in most cases. Sensitivity was high for both procedures. Because CT is more widely available and used, we suggest it as the initial study when determining resectability. In difficult cases, important complementary anatomic information can be derived from MR images obtained before surgical intervention.

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Malignant pleural mesothelioma is a locally aggressive neoplasm thought to be of mesodermal cell origin. Although the tumor may initially grow slowly, it is invariably fatal, accounting for approximately 1500 deaths each year in the United States [1]. The median length of survival after diagnosis is approximately 12 months [2]. The response to usual therapeutic options such as radiation and chemotherapy is dismal [3, 4]. A recent study [5], however, suggested that survival was improved in patients who had extrapleural pneumonectomy followed by radiation and chemotherapy. Although other studies have examined the radiologic findings of malignant mesothelioma [6-11], to our knowledge this is the first prospective study designed to determine if CT and MR imaging findings can be used to predict resectability in patients with biopsy-proved malignant mesotheliomas.

Subjects and Methods

Between February 1989 and April 1991, 41 consecutive patients were referred to our thoracic surgical clinic for resection of malignant pleural mesotheliomas. The diagnosis was established by careful examination of material obtained from pleural biopsy. Cell blocks with special stains including alcian blue, PAS, immunoperoxidase staining for carcinoembryonic antigen, and leucine M1 were used for histologic diagnosis. Electron microscopy and cytogenetic analysis also were performed in many cases. A quantitative asbestos fiber count in digested lung tissue was done to determine prior asbestos exposure.

CT scans of 22 patients were obtained at other facilities. We obtained scans in 19 patients

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by using a Somatom Plus or DRH system (Siemens Medical Systems, Iselin, NJ). Slice thicknesses and intervals were either 10 mm (Somatom Plus studies) or 8 mm (DRH studies). Both mediastinal and lung windows were photographed. All 41 scans were comparable in quality and technique, except that IV contrast medium was not used in our studies; it was used randomly in studies done at other facilities.

A 1.5-T magnet (GE Signa, Milwaukee, WI) was used for all MR imaging. ECG- or pulse-gated T1-weighted coronal images, 460–900/20 (TR/TE), with a 256 × 128 matrix and four excitations were obtained first. Then, cardiac-gated T2-weighted dual-echo axial images (1800–2400/20,80, 256 × 128 matrix, two excitations) were obtained. Sagittal multiplanar, flow-compensated, gradient-refocused images with cardiac gating also were obtained from the lateral chest wall through the mediastinum of the affected side (460–900/13, 30° flip angle, 256 × 128 matrix, four excitations). Respiratory ordering of phase-encoding gradients was used in all pulse sequences, and presaturation pulses in the superior and inferior planes were used in all spin-echo sequences. The slice thickness was 10 mm, with a gap of 2.5–5.0 mm. The field of view was 32–40 cm.

The interval between CT and MR imaging was less than 2 weeks in 22 (54%) of 41 patients, 2–4 weeks in eight (20%), and more than 4 weeks in 11 (27%). In only one patient were studies separated by more than 10 weeks. MR imaging was the last preoperative radiologic examination performed in the 34 patients who had surgery; it was performed 2 weeks or less before surgery in 24 patients (71%), 2–4 weeks before surgery in nine (26%), and more than 4 weeks before surgery in one (3%). Each CT and MR examination was reviewed independently by at least two thoracic radiologists. Differences in opinion were settled by consensus.

Patients with resectable mesothelioma at surgery had tumor of any size confined to one hemithorax, superficial invasion of the diaphragm or visceral pericardium, or focal invasion of the chest wall at the previous biopsy site, and these structures were removed en bloc at pneumonectomy. Patients with surgically unresectable tumors included those with transdiaphragmatic extension, diffuse invasion of the chest wall (tumor extending beyond the focal biopsy site), invasion of essential mediastinal structures (great vessels, esophagus, trachea, aorta, and heart), or distant metastases.

The radiologic criteria for resectability included preservation of extrapleural fat planes, normal CT attenuation values and MR signal characteristics of adjacent structures, absence of an extrapleural soft-tissue mass, and a smooth inferior diaphragmatic surface. The radiologic criteria for unresectability included tumor encasing the diaphragm; invasion of extrapleural soft tissue or fat; infiltration, displacement, or separation of ribs by tumor; or bone destruction. Given the locally aggressive nature of the tumor, further preoperative radiologic evaluation for metastases was performed only for specific problems.

For statistical analysis, tumors that met the radiologic criteria of resectability and were found to be resectable at surgery were considered true-positives. Tumors that met the radiologic criteria for resectability but were unresectable at surgery were considered false-positives. Tumors that were considered unresectable on the basis of radiologic findings were considered true-negatives if they were unresectable at surgery and false-negatives if they were resectable. The sensitivities and specificities of CT and MR for predicting resectability were calculated for three anatomic regions: the chest wall, the diaphragm, and the mediastinum. Sensitivity was defined as true-positive/(true-positive + false-negative). Specificity was defined as true-negative/(true-negative + false-positive).

Forty-one patients, 11 women and 30 men 16–72 years old (mean, 54 years), were initially examined. Six were not good candidates for surgery because of underlying medical problems, and one declined surgery. The final study group included 34 patients. All 34 had surgery

beginning with an upper abdominal incision and exploration of the inferior diaphragmatic surface. If this area was resectable, the incision was then extended to the thorax for extrapleural dissection. Potentially unresectable regions as suggested by imaging studies were explored first. If an unresectable area was encountered, exploration was terminated.

The gross specimen was thoroughly examined and multiple microscopic sections were obtained, particularly in areas with questionably invasive tumor margins.

Results

Twenty-three (56%) of the initial 41 patients had a known history of asbestos exposure, with a quantitative asbestos fiber count of 2717 asbestos bodies per gram of lung tissue (range 485–6423; <500 asbestos bodies per gram is considered normal). Fifteen patients (37%) had no obvious history of asbestos exposure and had an average asbestos fiber count of 367 (range, 63–1940). A history and fiber count were not available for three patients (7%). Of interest, contralateral pleural plaques or thickening was seen on CT in only five (12%) of 41 patients, and the extent was minimal in these cases.

Ten of 34 patients had surgically unresectable tumors: two with diaphragmatic invasion, four with chest wall invasion, and four with mediastinal involvement. Only partial radiologic and surgical correlation was possible in these patients. Full surgical and pathologic correlation with CT and MR findings was available in the 24 patients who completed extrapleural pneumonectomy. No patient who completed pneumonectomy had radiologically enlarged mediastinal lymph nodes (short axis, >1 cm), and no abnormal mediastinal nodes were found at surgery or on pathologic examination.

Thirty-two patients had surgically resectable tumors at the diaphragm (Table 1). The sensitivities and specificities of CT and MR in predicting resectability are recorded in Table 2. CT findings indicated resectability in 30 (94%) of 32 patients, and MR findings did in 31 (97%) of 32 patients (Fig. 1). The two

TABLE 1: Comparison of CT and MR Imaging in Predicting the Resectability of Malignant Pleural Mesotheliomas

Location of Tumor/ Imaging Study	Imaging Findings	Findings at Surgery (n = 34)	
		Resectable	Unresectable
Diaphragm	CT	Resectable	30
		Unresectable	2
	MR	Resectable	31
		Unresectable	1
Chest wall	CT	Resectable	25
		Unresectable	2
	MR	Resectable	27
		Unresectable	0
Mediastinum	CT	Resectable	24
		Unresectable	0
	MR	Resectable	22
		Unresectable	2

TABLE 2: Sensitivities and Specificities of CT and MR for Predicting the Resectability of Malignant Pleural Mesotheliomas

Location of Tumor/ Imaging Study	Sensitivity	Specificity
Diaphragm		
CT	0.94	0.50
MR	1.00	0.50
Chest wall		
CT	0.93	0.25
MR	1.00	0.25
Mediastinum		
CT	1.00	0.25
MR	0.92	0.50

Note.—Imaging findings were correlated with findings at surgery.

patients in whom CT findings incorrectly suggested unresectability (false-negatives) had tumor involving the right hemithorax. In these cases, the interface between the diaphragm and liver was indistinct, and a questionable soft-tissue mass extended below the diaphragm (Fig. 2). MR findings were false-negative in one of these cases also. The MR images showed minimal inferior diaphragmatic irregularity with increased signal on sagittal images, falsely suggesting transdiaphragmatic tumor invasion.

Two patients had unresectable tumors at the diaphragm. Only one of these cases was predicted correctly on the basis of CT and MR findings (Fig. 3). In the false-positive case, the tumor was on the right side, and MR images (Fig. 4) and CT scans showed an indistinct interface between the diaphragm and liver and no extension of tumor through the diaphragm. At surgery, the liver was found to be studded with small tumor nodules.

After diaphragmatic exploration, 31 of the 32 remaining patients had exploration at the chest wall. The other patient

had exploration at the mediastinum first, and the tumor was unresectable; consequently, the chest wall was not examined. Twenty-seven (87%) of 31 patients had resectable mesothelioma at the chest wall (Table 1). CT findings indicated resectability in 25 (93%) of 27 patients and MR findings did in 27 (100%). In two cases in which CT findings incorrectly indicated resectability (false-negatives), the scans showed poorly defined soft-tissue infiltration of fat in the lateral chest wall and distortion of normal muscle planes (Fig. 5). Pathologic examinations showed scar tissue from previous biopsies, and one of these patients had minimal tumor infiltration within the biopsy track. MR in these two patients showed the focal nature of infiltration not appreciated on CT. This was correctly interpreted as changes associated with biopsy, and the findings suggested that localized chest wall resection was possible at the time of pneumonectomy. Minimal tumor involvement of the track, however, was not predicted.

Four patients had unresectable tumors at the chest wall. CT findings indicated unresectability in only one (25%) of four patients and MR did in two (50%) of four patients (Fig. 6). The three cases in which the CT findings were false-positive included the two cases in which the MR findings were false-positive. Although the interface between the tumor and the chest wall was irregular, no definitive signs of unresectability were detected. At surgery, and in pathologic sections, superficial invasion of the chest wall was observed, and a dissection plane was not possible.

After diaphragmatic and chest wall exploration, 28 patients had exploration at the mediastinal border; 24 of these had resectable mesotheliomas (Table 1). CT findings indicated resectability in 24 (100%) of 24 patients and MR findings did the same in 22 (92%) of 24. In the two cases in which the MR findings were false-negative, tumor occurred in the lower portion of the thorax adjacent to the heart, where poor cardiac

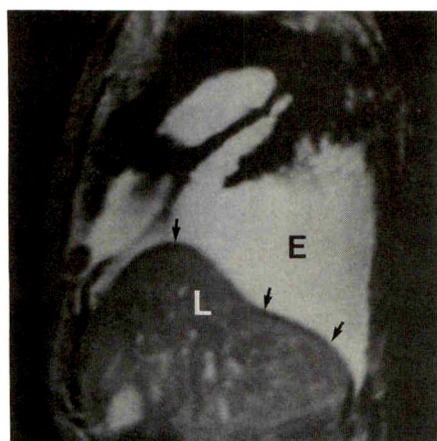
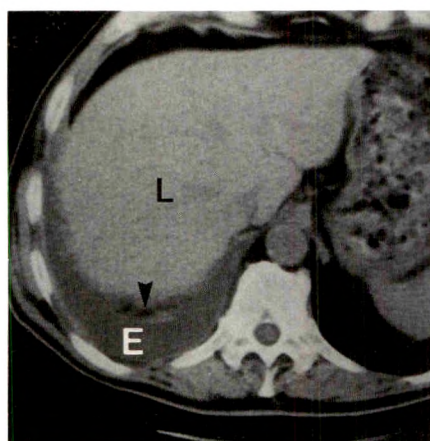
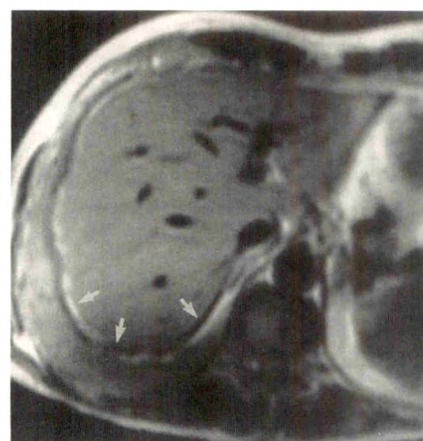


Fig. 1.—56-year-old man with resectable malignant mesothelioma. Sagittal gradient-refocused MR image shows a normal diaphragm as a well-defined low-signal structure (arrows) between large pleural effusion (E) and liver (L).



A



B

Fig. 2.—68-year-old man with resectable malignant mesothelioma.

A, CT scan shows tumor and pleural effusion (E) indistinguishable from indistinct right hemidiaphragm (arrowhead). No distinct plane is seen between diaphragm and liver (L), although no invasion was found at surgery.

B, Axial T2-weighted MR image shows low-signal diaphragm (arrows) and no evidence of transdiaphragmatic extension.

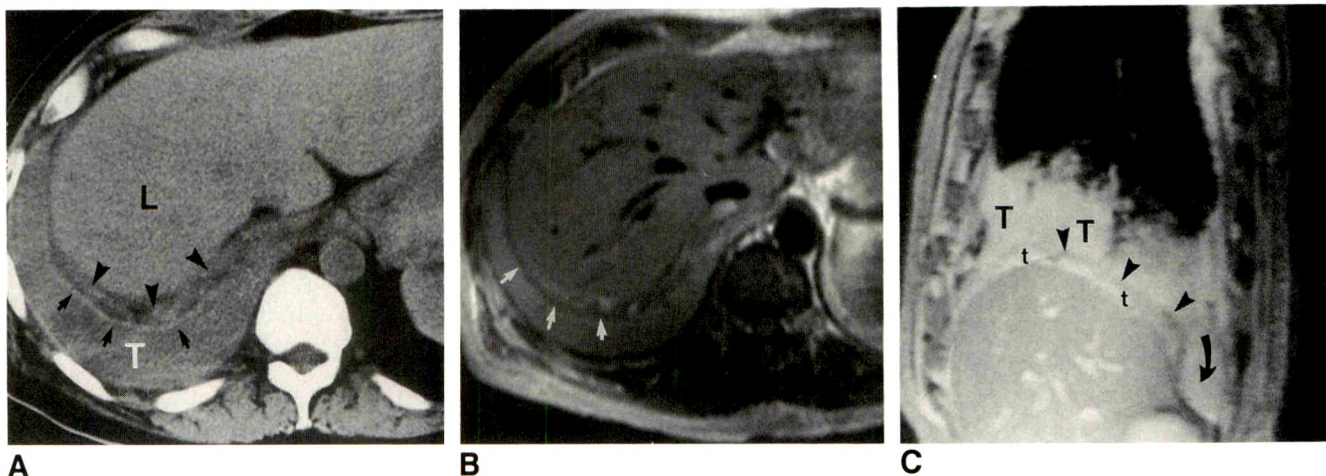


Fig. 3.—54-year-old man with unresectable malignant mesothelioma.

A, CT scan shows tumor encases right hemidiaphragm (arrows), with tumor posteriorly (T) and anteriorly (arrowheads) in subphrenic space next to liver (L).

B, Axial MR image shows similar findings, with tumor on both sides of right hemidiaphragm (arrows), precluding resection.

C, Sagittal MR image shows high-signal tumor (T) within thorax and within abdomen (t), outlining diaphragm as a low-signal structure (arrowheads). This was consistent with transdiaphragmatic extension. Note also inversion of diaphragm posteriorly (arrow).

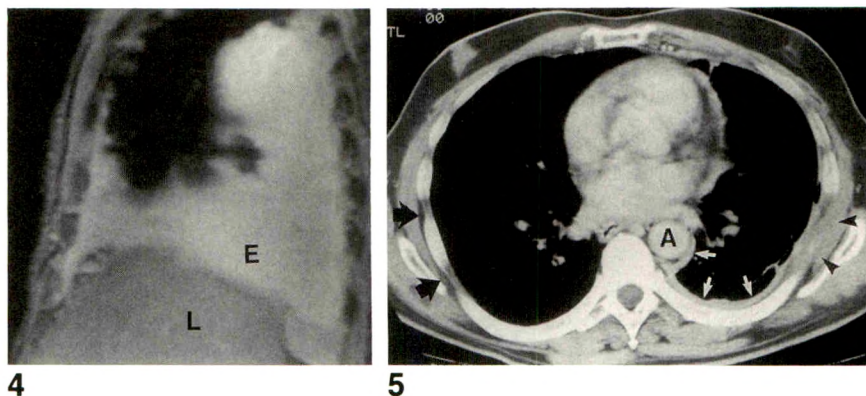


Fig. 4.—56-year-old man with unresectable malignant mesothelioma. Sagittal MR image shows indistinct interface between liver (L) and large pleural effusion (E). No definite transdiaphragmatic extension of tumor is seen, although diaphragm is not well visualized.

Fig. 5.—53-year-old man with resectable malignant mesothelioma. Contrast-enhanced CT scan shows a thin rim of tumor surrounding inferior aspect of left hemithorax (white arrows) and extending around lateral wall of descending aorta (A), although tumor is separated from aorta by a clear fat plane. Note disruption of fat planes and thickening of extrapleural soft tissues along left posterolateral chest wall (arrowheads). This was associated with a recent biopsy, and no tumor invasion was found at surgery. Chest wall on right side (black arrows) is normal.

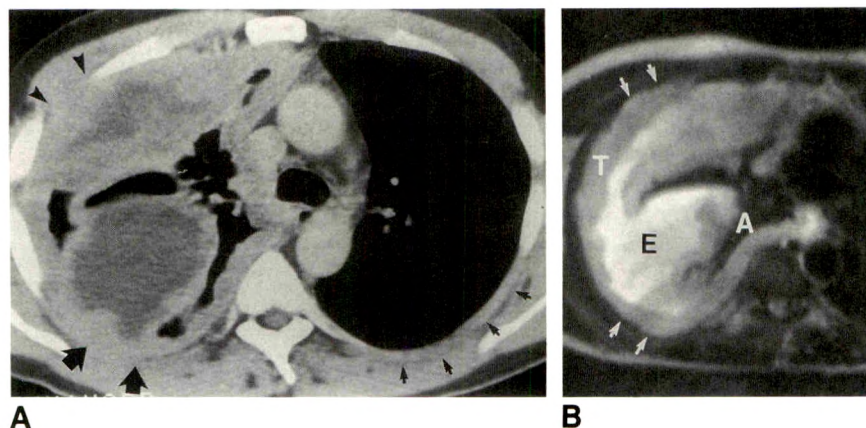


Fig. 6.—41-year-old man with unresectable malignant mesothelioma.

A, Contrast-enhanced CT scan shows a lobular tumor mass with moderate right-sided pleural effusion, disruption of posterior chest wall fat planes (large arrows), and minimal spreading of anterior ribs (arrowheads). Extensive invasion of chest wall was present at surgery. Normal chest wall is seen on left side (small arrows).

B, Axial T2-weighted MR image also shows tumor infiltrating chest wall (arrows). Pleural effusion (E) has a high signal and is well differentiated from surrounding tumor rind (T), which has a lower signal but remains brighter than adjacent muscle. Atelectatic lung (A) has a low signal.

gating and a phase-encoding artifact caused an appearance of local tumor invasion of the heart.

Four of the 28 patients had unresectable mesothelioma at the mediastinal border. CT findings indicated unresectability

in one (25%) of four patients (Fig. 7) and MR findings did in two (50%) of four. The three cases in which the CT findings were false-positive included the two cases in which the MR findings were false-positive. Tumor was contiguous with and

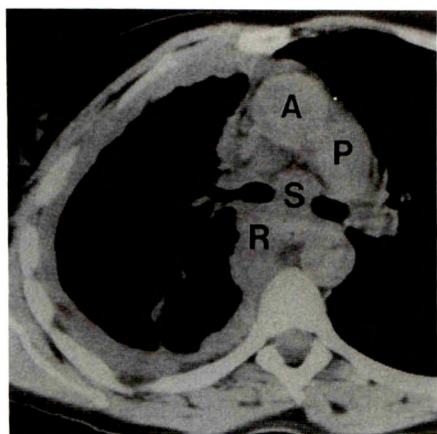
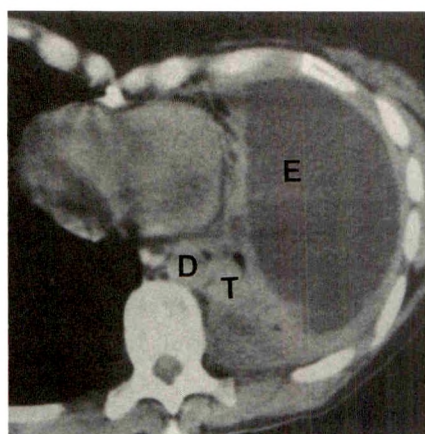
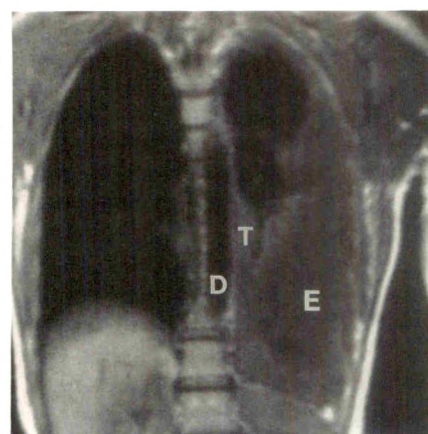


Fig. 7.—45-year-old woman with unresectable malignant mesothelioma. CT scan shows lobular tumor rind with direct extension into azygoesophageal recess (R) and invasion of subcarinal space (S). Tumor is adjacent to ascending aorta (A) and pulmonary artery (P).



A



B

Fig. 8.—35-year-old woman with unresectable malignant mesothelioma.

A, CT scan shows a tumor rind surrounding left hemithorax with a large pleural effusion (E). Tumor (T) was contiguous with and inseparable from descending aorta (D). At surgery, aortic invasion precluded resection.

B, MR image shows tumor (T) extending along descending aorta (D). No fat plane separates mass from mediastinum. Note large effusion (E).

inseparable from adjacent mediastinal structures, without clear signs of invasion. Superficial invasion of the aorta was found in one case (Fig. 8), and tumor invaded the superior vena cava in the other two patients.

Discussion

Malignant mesothelioma is a locally aggressive, invariably fatal tumor that usually causes progressive pulmonary compromise. Treatment options have traditionally been limited to palliative measures, including radiation, chemotherapy, and pleurectomy. Extrapleural pneumonectomy is an extensive and aggressive procedure, in which the pleura, lung, diaphragm, and visceral pericardium if invaded are removed en bloc. If the selection of patients is judicious, surgery can increase the length of survival.

Although the number of cases in our study was small, and statistical analysis limited, useful information on resectability for extrapleural pneumonectomy was derived. The diaphragm is a dome-shaped, flexible soft-tissue structure and is well seen by CT and MR. The most reliable findings indicative of resectability were a clear fat plane between the inferior diaphragmatic surface and the adjacent abdominal organs and a smooth inferior diaphragmatic contour. Conversely, a soft-tissue mass encasing the hemidiaphragm was consistently unresectable. Poorly defined margins between abdominal structures and a poorly visualized inferior diaphragmatic surface were indeterminate findings seen more commonly in patients with resectable mesothelioma, but also found in those with unresectable tumors. This was a particular problem with CT, as scanning was limited to the axial plane. MR provided additional coronal and sagittal images that could help clarify the situation. Understandably then, more CT than

MR findings will be indeterminate, but the small numbers of patients limited statistical comparison in our study.

MR findings were slightly better than CT findings for predicting resectability at the chest wall, again in part because MR provides images in multiple planes. Patients with resectable tumors had normal extrapleural fat and muscle with preservation of intercostal spaces and normal signal characteristics in the chest wall on MR images. On CT, findings indicative of invasion and unresectability included infiltration of the extrapleural soft tissues and displacement of ribs. Consistent MR findings that indicated unresectability of tumor in the chest wall included alteration in signal characteristics, best seen as increased signal intensity on the second echo of the T2-weighted sequence, and contiguous extension of tumor from the adjacent pleural space. Signal abnormalities due to cicatricial changes after biopsy were indistinguishable from minimal focal tumor invasion, but in any case these patients had resectable disease. Diffuse superficial tumor invasion, however, was almost impossible to detect in a small number of patients, although a diffuse irregular interface between the chest wall and tumor suggested the possibility of invasion.

For all resectable tumors at the mediastinum, CT and MR showed preservation of normal mediastinal fat without tumorous infiltration of soft tissues. Tumor was often contiguous with and inseparable from mediastinal structures, with displacement, not encasement, of the mediastinum. The most reliable feature of unresectable tumors on either CT or MR was infiltration of soft tissue, with loss of normal fat planes, although tumor surrounding more than 50% of a mediastinal structure without direct evidence of invasion also was suggestive of unresectability. In the two patients with resectable tumors that were thought to be unresectable on the basis of radiologic findings, MR images showed apparent infiltration

of adjacent mediastinal structures by tumor and subtle changes in signal characteristics on both coronal T1-weighted and axial T2-weighted images. This was a consequence of phase-encoding artifacts and degradation of spatial resolution. Subtle findings on MR images depend on clear resolution of the pleural-mediastinal interface, and proper gating is imperative.

Both MR and CT had high sensitivities in all three regions, but the assessment of specificity was practically impossible because of the small number of patients who had unresectable tumors (Table 2). Because of the small number, we could not compare the two techniques statistically. The rarity of the tumor placed limitations on the study. The only patients were ones seen in the thoracic clinic; thus, the study was confined to a select population of persons whom a diverse group of referring physicians considered candidates for surgery. This selection bias not only distorted the spectrum of disease but also limited the numbers of patients. CT was the first imaging study because the technique was more readily available and consistently used in the community. This may have biased the extent of disease predicted on the basis of CT vs MR findings, as MR imaging was done closer to the time of surgery, when progression of tumor may have occurred. In most patients, however, CT and MR were performed within a short time of each other, and we do not believe that the interval between CT and MR affected the results. The lack of contrast-enhanced CT scans may have limited our ability to detect local invasion; however, we found no difference in the prediction of resectability between findings on enhanced and unenhanced scans, and, to our knowledge, no large controlled studies have shown a statistically significant advantage in using contrast-enhanced CT scans to detect locally invasive disease.

In patients with malignant pleural mesotheliomas considered for resection, we suggest CT as the first imaging study. It is readily available and provides a significant amount of anatomic detail, and the results can be used to exclude from surgery those patients with obviously unresectable tumors.

MR can then be used as the final preoperative radiologic examination to complement CT, particularly in questionable cases. Correlation of all imaging studies is invaluable in directing exploration to areas of possible invasion, thus limiting the procedure in patients with unresectable tumors. Similarly, the studies are essential in selecting those patients who may benefit from extrapleural pneumonectomy, which may offer some hope for an otherwise devastating disease.

ACKNOWLEDGMENT

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Pictorial Essay

Radiographic Appearance of Bullet Tracks in the Lung

Paula Y. George¹ and Philip Goodman

Penetrating missile or bullet wounds to the lung result in a number of abnormalities visible on chest radiographs. One finding that is unique to pulmonary parenchyma is the bullet track, which occurs along the course of a bullet as it traverses the lung. A bullet track may occur in the lung because of this organ's low specific gravity and high elasticity. In other tissues, such as liver and brain, that have higher specific gravities and lower elastic content, bullet tracks are rarely, if ever, noted because widespread destruction usually occurs. Bullet tracks may have a delayed appearance on chest radiographs, and thus may cause confusion in interpretation if a history of injury is not elicited. With the increase in violent confrontations in the United States, it is more and more likely that radiologists will be asked to interpret chest radiographs of patients who have had penetrating bullet injuries to the thorax. In this pictorial essay, we illustrate the appearance of bullet tracks in lung on chest radiographs.

Formation of Bullet Tracks in Lung

Bullet tracks, representing pulmonary injury, occur along the course traversed by the bullet through lung tissue. Parenchymal damage from bullet wounds results from two different effects of injury: formation of a temporary cavity and formation of a permanent cavity [1]. The temporary cavity forms as the bullet passes through lung, causing local stretching and blunt trauma perpendicular to the path of the projectile. The temporary cavity is not visible on radiographs, as it occurs within a few milliseconds of passage of the bullet and resolves within a fraction of a second. The temporary cavity injures lung parenchyma surrounding the bullet path; the damage may be extensive, as the diameter of the temporary cavity is several

times larger than the bullet path and subsequent permanent cavity.

The permanent cavity is formed as the advancing bullet crushes the tissue it strikes, and it is this cavity that is shown on radiographs as the bullet track [2]. The cylindrical or rounded shape of the bullet track in lung is due to the high elastic recoil of the lung parenchyma, which converts a flat, linear laceration into a more rounded, elongated cavity. This is similar to what is seen with lung cysts resulting from blunt trauma of the chest. However, because of the continued forward motion of the bullet, lung cysts due to a missile wound are less spherical and more cylindrical than those resulting from blunt trauma.

The degree of damage to the lung and the size and configuration of the parenchymal bullet track are dependent on several properties of the bullet and of the tissue through which it passes. The contributing properties of the bullet that affect its wounding capability include the mass and velocity of the bullet, the shape of the projectile, the yaw or orientation of the bullet as it strikes tissues, and whether the bullet fragments or deforms on impact. The contributing properties of the bullet have recently been well described by Hollerman et al. [1]. The properties of tissue that affect the extent and type of injury are primarily its specific gravity and elasticity. Lung tissue has a low specific gravity (0.4–0.5), as compared with skeletal muscle (1.02–1.04) and rib (1.11), and also has a high elastic content, which resists deformity otherwise caused by the bullet [3]. Both of these properties minimize the effects of the temporary and permanent cavities in the lung. Thus, the lung is somewhat resistant to gunshot

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wounds, which in tissues of higher specific gravity and lower elastic content, such as brain and liver, may cause widespread destruction and, in many instances, death.

Appearance of Bullet Tracks on Chest Radiographs

The appearance of a bullet track on chest radiographs evolves through several stages. Initially, a poorly defined opacity is visible in the region of lung struck by the missile.

The size of the parenchymal abnormality depends on the amount of tissue injured (Figs. 1A, 2A, and 3A). In this initial stage, the bullet track is not well visualized because it is obscured by the surrounding parenchymal edema, contusion, and hemorrhage. In addition, because the pleura is disrupted, a pneumothorax or hemothorax may further mask underlying lung abnormalities (Fig. 4A).

Within 3–8 days, as the surrounding parenchymal opacification resolves, the bullet track becomes increasingly appar-

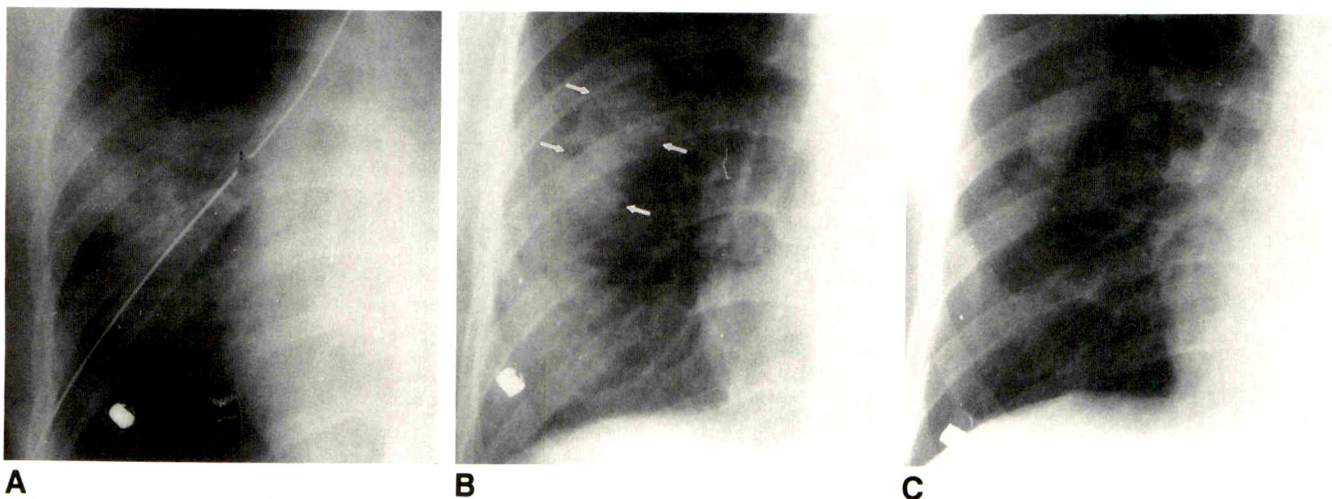


Fig. 1.—Small-caliber gunshot wound of right hemithorax.

A, Anteroposterior chest radiograph obtained on day of injury shows an opacity representing contusion in middle lobe of right lung. Bullet entered superolaterally and is lodged in lower lobe of right lung.

B, 3 days after injury, anteroposterior chest radiograph shows partial resolution of contusion; longitudinal course of bullet track (arrows) now can be seen.

C, Anteroposterior chest radiograph obtained 3 weeks after gunshot wound shows hematoma in a well-defined and narrower bullet track.

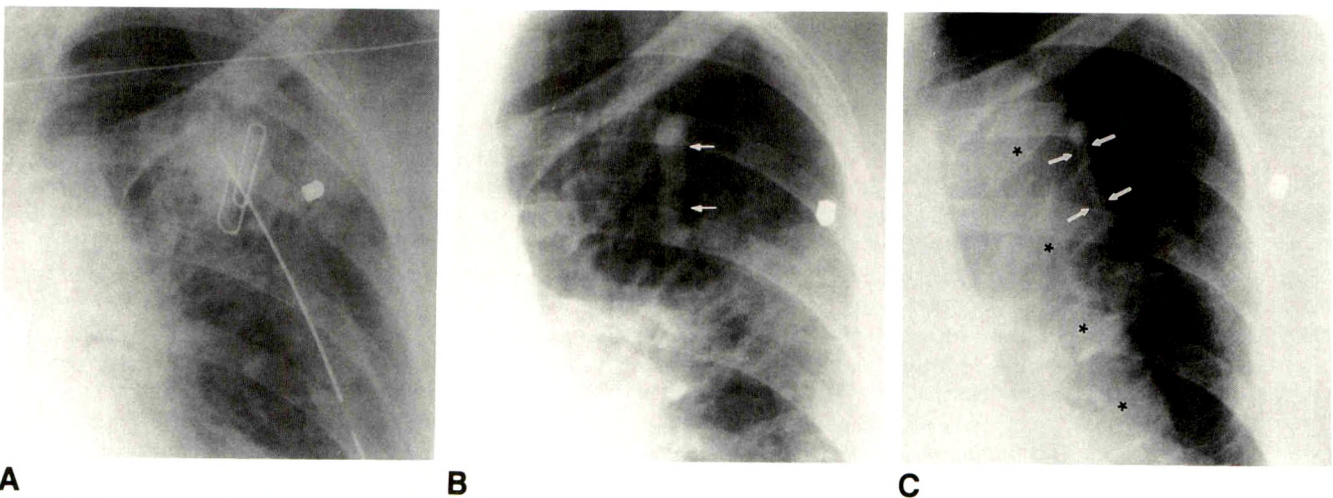


Fig. 2.—Small-caliber gunshot wound of left hemithorax.

A, Anteroposterior chest radiograph taken on day of injury shows a poorly defined opacity in left lung. Paper clip marks bullet's entry site, and bullet is seen lateral to this.

B, 8 days after injury, anteroposterior chest radiograph shows partial resolution of contusion in left lung. A tubular opacity, representing hematoma in bullet track (arrows), is now seen.

C, Anteroposterior chest radiograph obtained 3 weeks after injury shows interval decrease in size of bullet track (arrows). A large loculated posteromedial empyema (asterisks) that developed during this time is noted also.

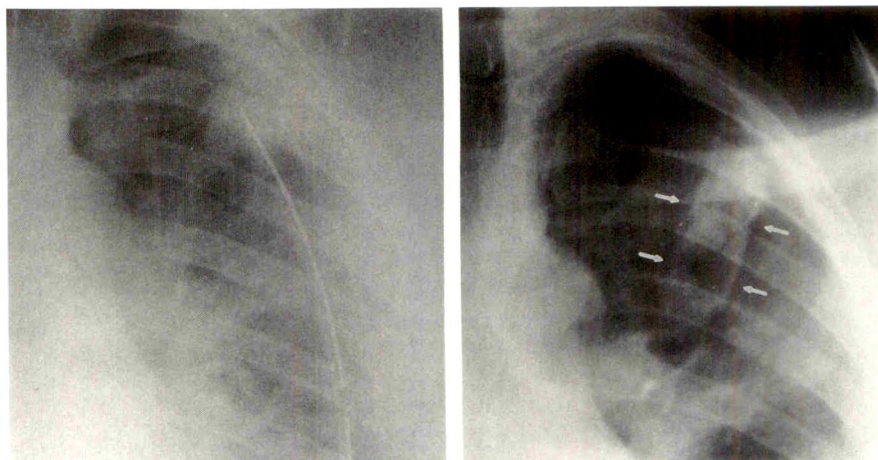
Fig. 3.—Large-caliber gunshot wound of left hemithorax. Bullet entered left supraclavical region and lodged just to left of lower thoracic spine.

A, Anteroposterior chest radiograph taken on day of injury shows consolidation, representing contusion, in upper lobe of left lung.

B, 6 days after injury, anteroposterior chest radiograph reveals a decrease in lung contusion. Bullet track (arrows) is filled predominantly with air.

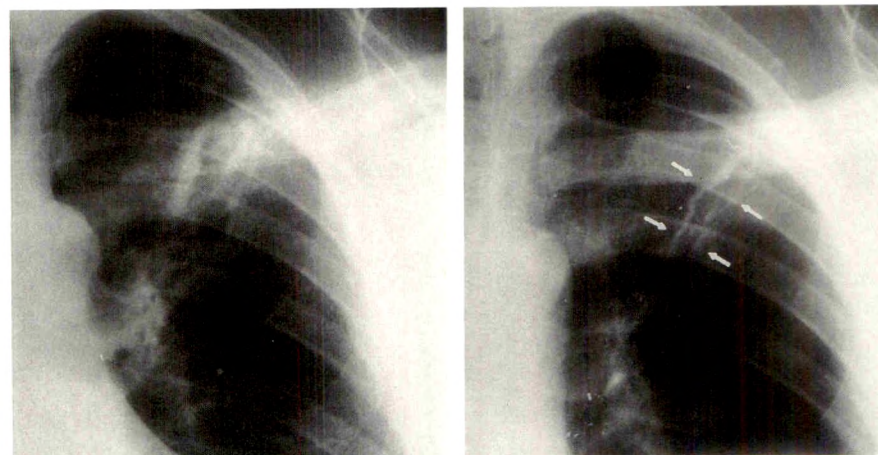
C, Anteroposterior chest radiograph taken 2 weeks after gunshot wound shows a decrease in size of air-filled bullet track.

D, Anteroposterior chest radiograph obtained 6 weeks after injury shows further resolution of bullet track (arrows), which has a parallel, linear, or "tram-track" appearance.



A

B



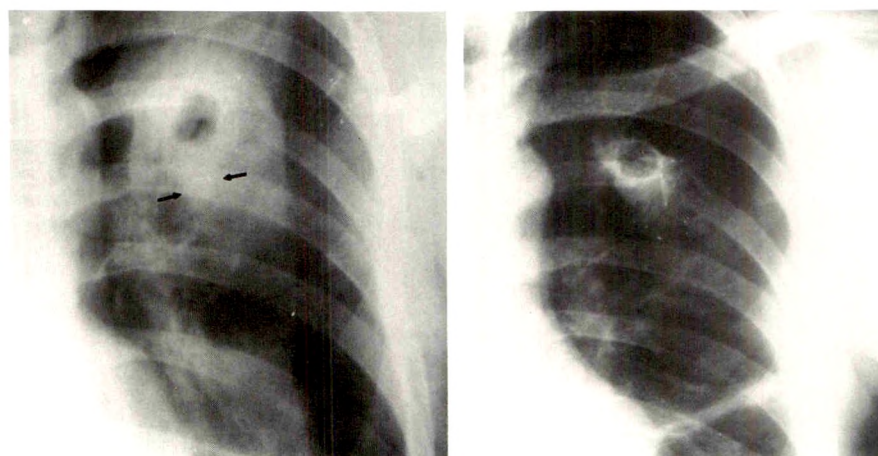
C

D

Fig. 4.—Large-caliber gunshot wound of left hemithorax.

A, Anteroposterior chest radiograph taken 2 weeks after gunshot wound to left hemithorax shows air-filled bullet track. An opacity inferior to the bullet track (arrows) represents bullet path extending laterally toward soft tissues of axilla. There is a hydropneumothorax.

B, Anteroposterior chest radiograph obtained 3 weeks after injury shows some resolution of surrounding contusion. Air-filled bullet track is seen en face and is now smaller.



A

B

ent on the chest radiograph (Figs. 1B, 2B, and 3B). The bullet track contains mainly blood/hematoma, and on radiographs has either a circular appearance if viewed en face or a tubular appearance if viewed in profile (Fig. 2B).

The hematoma in the bullet track resolves over weeks by "shrinking" or slowly diminishing in size from its periphery rather than by dissipating uniformly throughout its substance, and thus, it maintains the same orientation and shape as it

gets smaller (Figs. 1–3). As the hematoma resolves, an air-filled cavity or lung cyst may remain. At this stage, when viewed in profile on chest radiographs, these cavities have a parallel, linear, or "tram-track" appearance (Fig. 3D), and when seen en face, they are round with thin to moderately thick walls (Fig. 4B). The cavity usually resolves completely within a few months by contraction of surrounding scar tissue and compression from adjacent lung. In some cases, air may be seen in the bullet track within a few days of injury, after resolution of the surrounding contusion (Fig. 4A). This is perhaps a result of direct communication between the bullet track and the bronchial tree, allowing direct drainage of blood from the site of injury [2].

A delay or failure in resolution of the lung cavity should alert the radiologist to a possible infectious complication [4]. This is a particular problem, as bullet tracks are associated with a considerable amount of tissue destruction, necrosis, and occasionally foreign material, such as bone fragments or cloth-

ing. In addition, bacterial contamination from the cutaneous wound site at the time of injury is always a potential risk [1].

Bullet tracks in the lung may create difficulty and confusion in the interpretation of chest radiographs, particularly if a history of trauma is not elicited or if the potential for this type of abnormal finding on radiographs is not appreciated.

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Case Report

Bronchial Stenosis Due to Endobronchial Tuberculosis: Successful Treatment with Self-Expanding Metallic Stent

Joon Koo Han,¹ Jung-Gi Im,¹ Jae Hyung Park,¹ Man Chung Han,¹ Young Whan Kim,² and Young-Soo Shim²

Endobronchial tuberculosis is present in 10–40% of patients with active pulmonary tuberculosis, and more than 90% of the patients with endobronchial tuberculosis have some degree of bronchial stenosis [1]. The primary treatment for tuberculous bronchial stenosis is antituberculous chemotherapy combined with steroids, but some patients do not respond well, and more aggressive treatment is needed to restore the patency of the involved bronchus [1, 2]. Balloon dilatation of tuberculous bronchial stenosis has been reported to be successful [2]. However, in our experience, balloon dilatation of the stenotic segment has not significantly improved patients' clinical symptoms except in those with very short segmental stenosis. We describe a case of tuberculous bronchial stenosis that was successfully treated with Gianturco self-expanding metallic stents.

Case Report

A 28-year-old woman had had pleuritic chest pain and dyspnea for 1 month. A year earlier, she had been treated with antituberculous medications for pulmonary tuberculosis. On physical examination, respiratory sound was absent on the left side of the chest. Chest radiographs showed total collapse of the left lung (Fig. 1A). Bronchoscopic examination revealed focal narrowing of the left main bronchus with severe fibrotic changes suggestive of sequelae of endobronchial tuberculosis. Acid-fast bacilli were not shown on bronchoalveolar lavage and repeated sputum smears. Pulmonary function tests showed a forced expiratory volume in 1 sec (FEV₁) of 1.37 l and a forced vital capacity (FVC) of 1.62 l, 55.2% and 55.5%, respectively, of the predicted values.

With the patient under local anesthesia, a 10-French Nelaton catheter was inserted into the trachea under fluoroscopic guidance. Bronchography revealed a severe 3-cm-long stricture originating at the orifice of the left bronchus; the lobar bronchi were not shown. A 0.89-mm J-tipped guidewire (Terumo, Tokyo, Japan) was inserted in the Nelaton catheter, and after the Nelaton catheter was removed, a 5-French Berenstein catheter (Cook, Bloomington, IN) was inserted. With gentle manipulation of the catheter and wire, the wire could be passed across the stenotic lesion (Fig. 1B). Serial dilatation of the stenotic segment with a 4-mm coronary balloon dilatation catheter (Advanced Cardiovascular System, Mountain View, CA) and a 6-mm angioplasty balloon (Cook, Bloomington, IN) was performed. An 8.5-French, 32-cm-long Teflon sheath with an angled tip (Cook, Bloomington, IN) was then advanced across the lesion, and the dilator was removed. Two gold-coated Z-stents (10 mm in diameter, 3 cm long, made of 0.3-mm stainless steel wire, Myungsung Medical, Seoul, Korea) were inserted across the stenotic lesion, overlapping each other for 10 mm, from the carina to the orifice of the left lower lobe bronchus.

Immediately, the left lung was aerated, and the patient's dyspnea was much improved. For 3 days, she complained of a mild cough and increased amounts of sputum. Chest radiographs taken immediately after stent insertion showed an expanded left lung and restored tracheal patency; however, the stent was not fully expanded at the stenotic portion of the left bronchus. Leukocytosis ($13.8 \times 10^9/l$) was noted after the procedure; however, the WBC count returned to normal 2 days later with antibiotic treatment. Pulmonary function tests 9 days after the stent was inserted revealed an FEV₁ of 1.66 l and an FVC of 2.05 l, 67% and 70%, respectively, of the predicted values. One month later, FEV₁ was 1.68 l and FVC was 2.34 l, 68% and 80%, respectively, of predicted values. Bronchoscopy 1 week after the procedure revealed a widely patent left main

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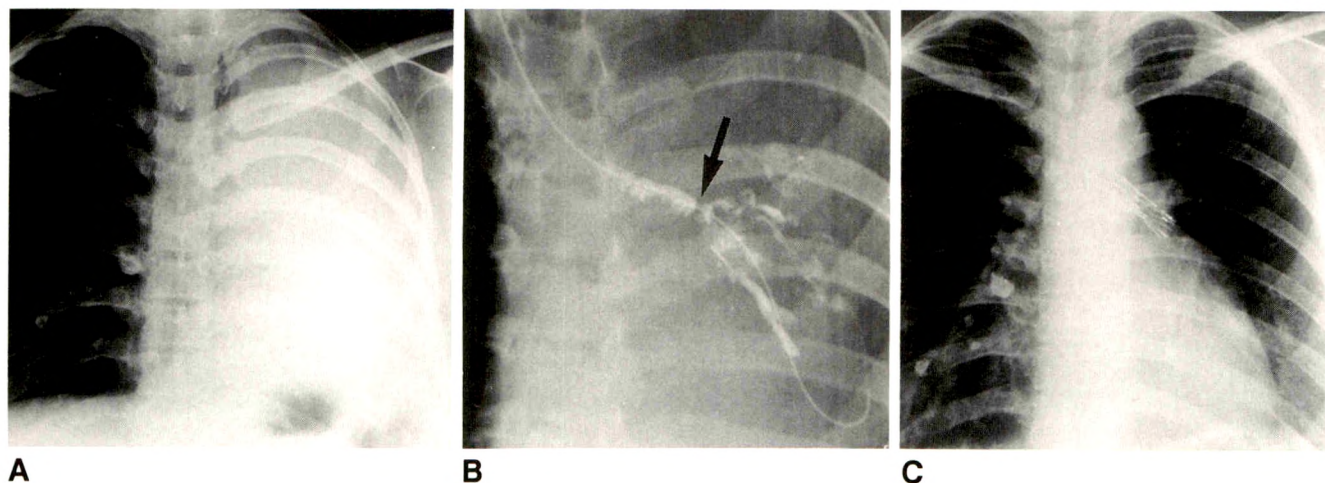


Fig. 1.—A, Initial chest radiograph shows total collapse of left lung.
 B, Selective left-sided bronchogram after passing of guidewire reveals diffuse irregular narrowing of left main bronchus. Also note a focal stenosis just proximal to left upper lobe bronchus (arrow).
 C, Chest radiograph taken 2 weeks after the procedure reveals fully expanded bronchial stent and left lung. Patient is free of symptoms.

bronchus. The stent partly overlapped the left upper lobe bronchus; however, the left upper lobe bronchus also was patent. Chest radiographs taken 2 weeks later revealed a fully expanded stent and a well-expanded left lung (Fig. 1C). The patient has now been asymptomatic for 6 months.

Discussion

Techniques used to treat bronchial stenosis include surgical resection, cryotherapy, laser photoresection, and balloon dilatation. However, surgery per se can induce tracheal stenosis, and laser photoresection or cryotherapy requires expensive instruments and experienced personnel [1, 2]. Balloon dilatation was first used to treat tracheobronchial stenosis by Cohen et al. [3] in 1984. Balloon dilatation to treat tuberculous bronchial stenosis was first reported in the English literature by Nakamura et al. [2] in 1991. Although balloon dilatation is less invasive and less costly than surgery and is easy to perform, restenosis of the dilated bronchus occurs frequently. Chung et al. [1] reported restenosis in 37.5% of their cases 1 month after the procedure. Also, balloon dilatation in fibrotic endobronchial tuberculosis disrupts the supporting tissues and creates acquired bronchomalacia to some degree. Thus, despite the apparent increase in diameter of the narrowed bronchus during inspiration, the airway collapses during expiration which leads to increased wheezing sounds and almost no increase in FEV₁ as compared with a significant increase in FVC [1]. Thus, the principal role of the endobronchial stent in tuberculous bronchostenosis is not only dilatation, but also supporting the labile bronchial wall.

Gianturco self-expanding metallic stents are used to treat stenosis in the vascular and biliary systems. Also, several reports have described the use of stents in the tracheobronchial system in cases of malignant tumors, postoperative strictures, tracheobronchomalacia, and relapsing polychondritis [4–8]. To our best knowledge, no English-language reports describing the use of a self-expanding metallic stent to treat tuberculous bronchial stenosis have been published.

We also successfully treated another patient with a collapsed left lung resulting from tuberculous bronchial stenosis with a Gianturco-type stent. That patient too has been asymptomatic for 1 month.

The advantage of the self-expanding metallic stent is that it can be used with the patient under local anesthesia, it is easy to perform, and does not occlude tributaries of the airway even if the stents override the opening of the branches of the airways. Once the respiratory epithelium covers the stent, local inflammation decreases [8]. A major disadvantage is that it cannot be removed endoscopically or radiologically. Data on the long-term effects of the metallic stent in humans are insufficient. However, the stent can restore the patency of the airway promptly and supports the airway against increased thoracic pressure during expiration. The self-expanding metallic stent can be a good method for treatment of tuberculous bronchial stenosis that does not respond to medical therapy.

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Screening Mammography in 350 Women with Breast Implants: Prevalence and Findings of Implant Complications

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 Barbara S. Monsees¹
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 V. Leroy Young²
 Thomas K. Pilgram¹

OBJECTIVE. A series of screening mammograms in asymptomatic women with breast implants was reviewed to determine the prevalence of clinically silent sequelae of breast augmentation and to analyze the mammographic findings.

MATERIALS AND METHODS. The screening mammograms of 350 consecutive women with implants were reviewed retrospectively by experienced mammographers. Any women who reported problems had a diagnostic examination and therefore were not included in our sample. Mammographic features of sequelae specific to implantation such as development of a fibrous capsule, periprosthetic calcification, implant herniation, and silicone leaks were tabulated. Additionally, modified compression (push-back) views, when obtained, were evaluated for their usefulness.

RESULTS. Fibrous encapsulation of breast implants was seen in 257 (73%) of 350 women. Periprosthetic calcification was seen in 90 (26%), and 60 women (17%) had implant herniations. Sixteen women (5%) had implant failure as evidenced by silicone leak. Two of these women had bilateral implant failures. Surgical confirmation was attainable in only five of 16 women. Analysis of modified compression views demonstrated an overall improvement in visualization of breast tissue with this technique. Although the sample size is small, there was a significant increase in the amount of breast tissue seen with push-back views in women with submuscular implants.

CONCLUSION. Our analysis revealed a wide range of mammographic findings in this group of asymptomatic women with breast augmentation. Especially worrisome is the 5% prevalence of unsuspected silicone extravasation. Additionally, we have demonstrated the usefulness of push-back views in this screening group, especially in women with submuscular implants.

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Silicone gel breast implants have recently been scrutinized by the medical establishment, the Food and Drug Administration, the lay public, and the media. The primary focus has been on the possible association of silicone gel implants with immune-complex diseases [1]. A second major issue has involved whether the presence of radiopaque implants in the augmented breast compromises mammography by obscuring the overlying glandular tissue, resulting in delayed diagnosis of breast cancer in these patients [2-8]. In this study, we retrospectively reviewed the screening mammograms of a group of asymptomatic women with breast implants.

Materials and Methods

We retrospectively analyzed screening mammograms of 350 consecutive women with breast implants who were examined between August 1986 and July 1991 at the Mallinckrodt Institute of Radiology. All mammograms had been obtained by using standard film-screen technique. Mediolateral oblique and craniocaudal views were obtained in all patients. The addition of modified compression (implant displacement, or push-back) views was begun in November 1988 as a routine part of the screening examination [9]. All women had no clinical

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signs or symptoms of breast cancer and were undergoing routine screening mammography. Patients with palpable abnormalities or a clinical question of implant rupture were referred for diagnostic mammography and were not included in this study. As standard practice, patients were allowed to refer themselves for screening mammography without a physician's request.

All patients having mammography completed a detailed questionnaire before leaving the department. Specific information available included the patient's age, family history of breast cancer, personal history of prior breast surgery, previous mammography, and summary of current problems, if any. When volunteered by the patient, the implant type, duration of implantation, and any breast pain or hardening of implants were noted; however, these had not been routine queries on the questionnaire.

All mammograms and questionnaires were reviewed retrospectively by two radiologists specializing in mammography. In all cases, the location of the implant was verified to be either subglandular (anterior to the pectoralis muscle) or submuscular (submusculofascial, posterior to the pectoralis muscle). When possible, the type of implant was noted to be saline, silicone, or a combination of the two materials. In addition, mammographic features that suggested sequelae specific to implantation were evaluated. These included a measurable periprosthetic dense band or a rim of tissue that might correlate with a fibrous capsule [10], calcification in the periprosthetic capsule [11], asymmetry of implant size or shape, focal herniation of a portion of the implant [12, 13], and implant rupture with deflation of the implant envelope or extravasation of silicone outside of the shell [14–18]. Two hundred three women (58%) had serial mammograms, but it was the most recent examination that was evaluated for the listed features. When implant rupture was suspected, all prior mammograms were reviewed to determine the age and stability of the mammographic findings.

The glandular tissue was evaluated for the presence of soft-tissue masses and microcalcifications. An attempt was made to quantify the amount of glandular tissue that could be evaluated by using mammography with modified compression views vs standard mediolateral oblique and craniocaudal views [19, 20]. The quality of the modified compression views was judged as excellent, good, fair, or poor on the basis of an estimate of how much better the breast tissue was visualized than with standard views. A rating of excellent corresponded to 75–100% extra tissue, good as 51–74% extra tissue, fair as 25–50% extra tissue, and poor as less than 25% extra tissue. Because actual calibration of the amount of breast tissue visualized was not done, this apparent increase in breast tissue may be artifactual and merely a result of better compression.

Statistical analysis of these data was by comparison of frequencies, because the information relevant to the research questions was in the form of classifications rather than measurements. Relationships between variables were examined through two-way frequency tables and tested with nonparametric statistics. Analytic procedures were carried out by using Systat software for the Macintosh personal computer.

Results

Three hundred six (87%) of 350 women had implants in the subglandular position, while 44 women (13%) had them in the submuscular position. The mean age of the women at their last mammographic examination was 46 years (range, 32–75 years). The age of a woman at the time of her initial surgery was available for 135 participants (39%). Of these, the mean age was 36 years (range, 22–70 years). One 75-year-old woman had had subglandular implantation at age 70. From

the same group of women, the mean age of the subglandular implants was determined as 10 years (range, 1–27 years). Although the sample size is small, the mean age of 15 submuscular implants was 7 years (range, 1–12 years). The exact type of implant, specifically regarding texture or coating of the envelope, was not known in most cases. Mammography showed that nine women probably had saline implants and that another 19 had double-lumen implants (silicone gel-filled sac surrounded by an outer saline-filled envelope). The remaining 322 women were presumed to have silicone gel-filled implants. Fifteen women specifically reported that they had polyurethane-coated implants.

Modified compression views were available for 252 of the 350 women. The improvement in visualization of glandular tissue with modified compression views is described for subglandular and submuscular implants (Table 1). The proportion of excellent mammograms is nearly 10 times greater for the submuscular position (68%) than for the subglandular position (7%). Fifty-three percent of the mammograms of subglandular implants were rated as fair or poor quality as compared with 6% of the mammograms of submuscularly placed implants. In none of the submuscular implants were the modified compression views considered poor.

Approximately half of all implants exhibited small, focal contour asymmetry. Implant herniation was defined as a focal, smooth outpouching of the envelope and contents without evidence of extravasated silicone (Fig. 1). These were subjectively graded as small, moderate, or large. A focal bulge 1 cm or smaller was graded as a small herniation, a bulge of 1–2 cm was graded as a medium-sized herniation, and a bulge larger than 2 cm represented a large herniation of the implant envelope. Implant hernias were more prevalent with subglandular implants than with submuscular implants. Fifty-seven (19%) of all 306 subglandular implants exhibited herniation of the implant; this was twice the rate of submuscular implants (7%, three of 44 cases). Of all hernias, eight were graded as large, 25 as moderate, and 27 as small.

Implant failure evidenced by extravasation of silicone was found in 16 (5%) of 350 women. No information is available as to whether these women had a history of trauma or of closed capsulotomy (vigorous manual compression of the augmented breast in an attempt to disrupt the fibrous capsule and to restore a softer more natural-feeling breast). The rate of implant leaks appears to be the same for the submuscular and subglandular locations. This conclusion is tenuous be-

TABLE 1: Quality of Modified Compression Views by Implant Location in 252 Patients

Quality of Mammogram	No. (%) by Implant Location	
	Subglandular	Submuscular
Excellent	15 (7)	23 (68)
Good	87 (40)	9 (26)
Fair	67 (31)	2 (6)
Poor	49 (22)	0 (0)
Total	218 (100)	34 (100)

Note.—Pearson χ^2 -test = 87.7; df = 3; $p < .001$.

cause of the small number of cases observed. No saline implants were found to be deflated.

Eighteen ruptured implants were found in 16 patients. Two of the 16 women had bilateral implant failure. These leaks were evaluated according to mammographic appearance and were described as smooth or flowing (Figs. 2 and 3), and streaky or irregular (Fig. 4) in shape. The size of the leaks was subjectively graded as small (Fig. 5), moderate, or large (Fig. 3), depending on how much extruded silicone gel was evident. Extravasated silicone distributed over less than a 2-cm² area was considered a small leak, whereas a moderate-sized leak was 2–5 cm². Leaks larger than 5 cm² or ones that demonstrated silicone granulomas or lymph node opacification were graded as large. Mammograms were inspected for the presence of silicone granulomas (small dense nodules, Fig. 4) and lymph nodes (Fig. 6) that were of greater opacity than normal.

Ten of the ruptures were classified as large silicone gel leaks, three were moderate, and five were small. Of the two patients with bilateral ruptured implants, one had large leaks bilaterally and the other patient had one small and one large leak. When a silicone gel leak was detected, prior mammograms, if available, were reviewed to determine when the leak occurred and whether it had changed in size. Eight patients had no prior mammograms. In four cases, the leak remained stable in size from the baseline mammogram obtained 1–4 years earlier. In one case, the rupture developed at some point after the baseline mammogram obtained 3 years earlier. In two cases, the silicone gel leak developed at some point during the screening interval and remained stable for 1 and 3 years, respectively. In only one case, the silicone gel leak increased in size from the baseline mammogram obtained 4 years earlier.

Only seven of the 18 ruptures in five of the 16 women were confirmed surgically. The remaining cases were not identified as ruptures prospectively; rather, the examinations had been interpreted as showing herniation or results were called normal. Therefore, these leaks are unproved and have had no known surgical follow-up. This retrospective review has resulted in our increased awareness of the mammographic spectrum of implant rupture. Recognition of cases of rupture not previously identified has prompted us to reexamine such patients. Surgical confirmation of rupture will be sought.

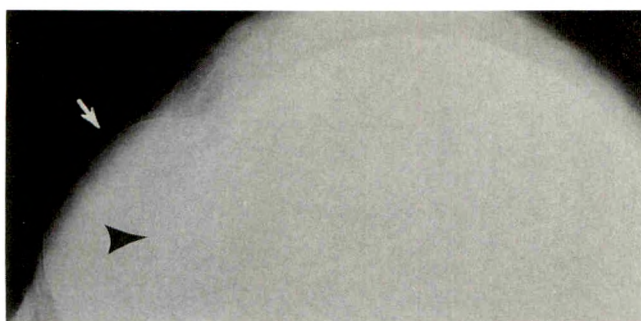


Fig. 1.—Craniocaudal mammogram of a double-lumen implant shows large, focal herniation of both outer saline (arrow) and inner silicone (arrowhead) sacs involving medial border of implant.

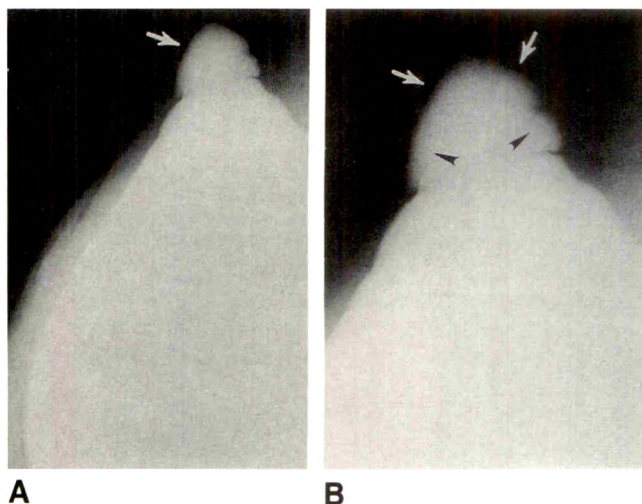


Fig. 2.—A, Mediolateral oblique mammogram of a submuscular silicone implant with conical shape superiorly shows small amount of extruded silicone gel (arrow) with flowing, slightly lobulated contour. B, Coned-down mammogram shows edge of implant envelope (arrowheads) within extruded silicone gel (arrows).

Eighty-three (24%) of 350 women exhibited periprosthetic capsular calcification, and it occurred more commonly in the subglandular position (27%) than in the submuscular position (4.5%). However, most of the submuscular implants in the study were in place for less than 10 years, and a smaller percentage of the envelope was visualized in the submuscular implants than in the subglandular ones. This is because of the inability to image the posterior aspect of the implant in the submuscular position in most cases. The prevalence of calcification in the subglandular position appears to be greater in patients who had had implantation 10 years ago or longer, but the results are not statistically significant. The calcification was described by the mammographer as plaque-like in 49%, fine or linear in 45%, and sawtooth in 4%; the remaining 2% contained a combination of calcifications (Fig. 7).

Two hundred fifty-seven women (73%) had a measurable periprosthetic rim of soft tissue (Fig. 8). No attempt was made to correlate this clinically with the Baker scale for capsular contracture [10]. The presence of a rim was noted to be much higher in the subglandular position (83%, 255 of 306) than in the submuscular position (5%, two of 44 cases); however, the overlying pectoralis muscle, which is of similar radiographic density, may have obscured the presence of a fibrous capsule around submuscular implants. The thickness of the rim ranged from 0.2 to 5 mm. One hundred ninety-seven women had a measurable rim thicker than 1 mm.

Twelve women had mammographic parenchymal abnormalities, including four with microcalcifications and eight with soft-tissue masses. Coned compression spot films and magnification views were obtained and/or compared with prior mammograms to evaluate these findings. In the cases of new or enlarging soft-tissue masses, sonography was done to determine if the lesion was cystic or solid. Of the four women with microcalcifications, two biopsies were performed. One of these showed lobular carcinoma in situ (lobular neoplasia),

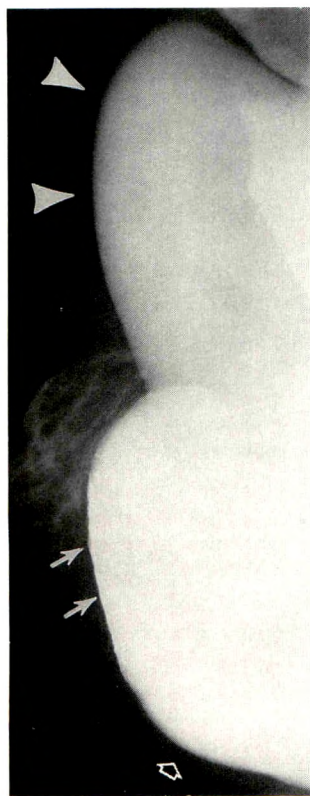


Fig. 3.—A, Mediolateral oblique mammogram of a subglandular implant with plaque-like calcification (solid arrows) in periprosthetic capsule. Implant rupture has resulted in large amount of extruded silicone gel superiorly (arrowheads) and smaller amount inferiorly (open arrow).

B, Craniocaudal mammogram confirms that implant has ruptured with silicone gel extruded from lateral (outer) aspect of envelope (arrow).

A

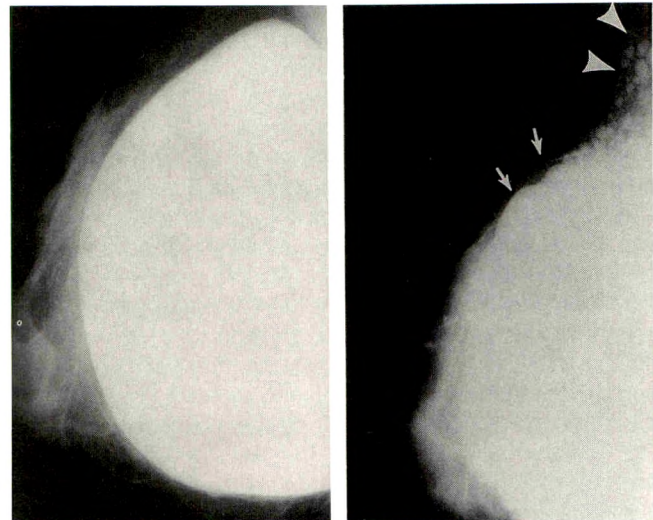


B

and the other patient had a 4-mm ductal carcinoma in situ. Only one of the eight soft-tissue masses warranted biopsy, and it proved to be a stage II invasive ductal carcinoma.

Discussion

Screening mammograms of 350 asymptomatic women with breast implants examined between August 1986 and June 1991 were retrospectively analyzed to evaluate the prevalence of clinically silent sequelae as detected with mammography. Previous authors have noted that breast implants are radiopaque on film-screen mammography and may obscure overlying glandular tissue [2–6]. Anecdotal reports have described calcium deposits in the periprosthetic capsules [11],

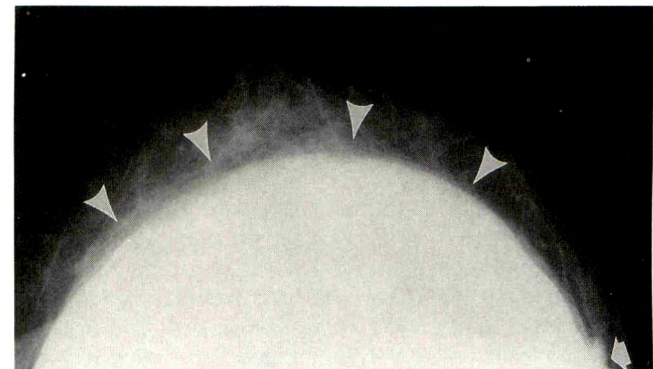


A

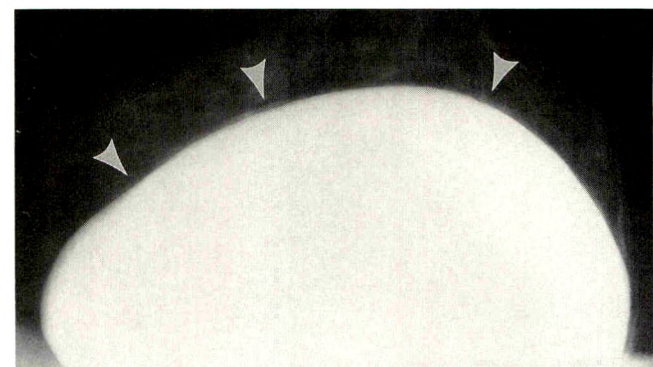
B

Fig. 4.—A, Mediolateral oblique mammogram of an intact subglandular implant.

B, Mediolateral oblique mammogram 1 year later shows lobulated contour of anterior wall of implant with large amount of extruded silicone (arrows) and formation of multiple silicone granulomas (arrowheads).



A



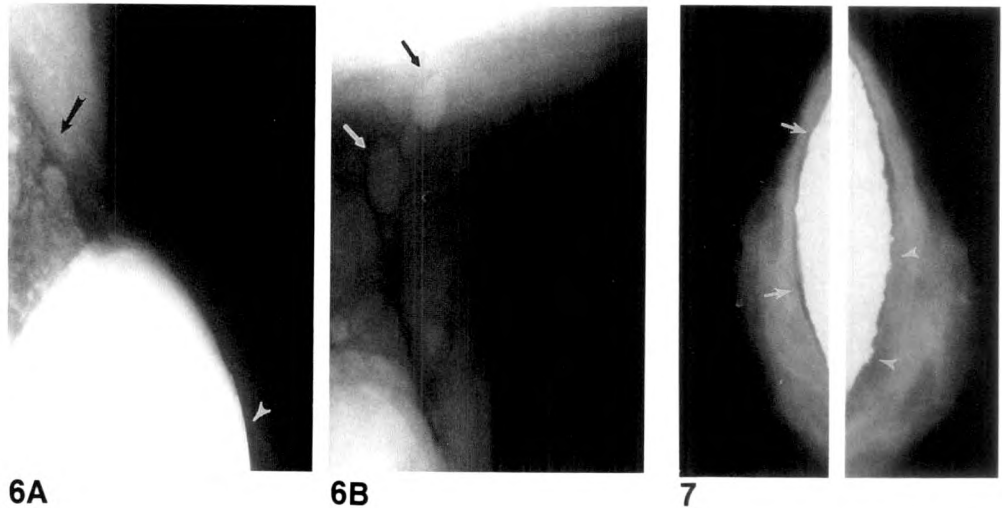
B

Fig. 5.—A and B, Craniocaudal (A) and mediolateral oblique (B) mammograms show small amount of extruded silicone gel (arrow in A) adjacent to medial aspect of implant envelope. Rupture is obscured by dense implant in mediolateral oblique view. Note thin periprosthetic rim of soft tissue (arrowheads) on both views.

Fig. 6.—A, Coned-down mammogram of a ruptured subglandular implant shows coalescence of numerous silicone granulomas (arrow) and fine, linear calcification of periprosthetic capsule (arrowhead).

B, Coned-down mammogram of same patient with long-standing implant rupture shows opacification of numerous axillary lymph nodes by uptake of silicone gel (arrows).

Fig. 7.—Craniocaudal mammogram of both breasts shows intact silicone gel implants with combination of plaque-like (arrows) and sawtooth (arrowheads) calcifications in periprosthetic capsule.



implant diverticula (herniations) [12–14], and ruptured implants [15–18].

The prevalence of a periprosthetic rim was similar in women with a long or short history of implantation. This suggests that in the subglandular position this rim occurs in the immediate postoperative period and persists. A similar observation was made with respect to the prevalence of herniation found in 17% of patients. This also suggests that herniation occurs quickly and persists. There was a statistically significant correlation between the presence of a periprosthetic rim and implant herniation. This supports the theory that capsular contracture may correlate with a periprosthetic rim and that closed capsulotomy could result in herniation of the implant envelope through a fissure created during capsulotomy. The degree of implant herniation may be exaggerated as a result

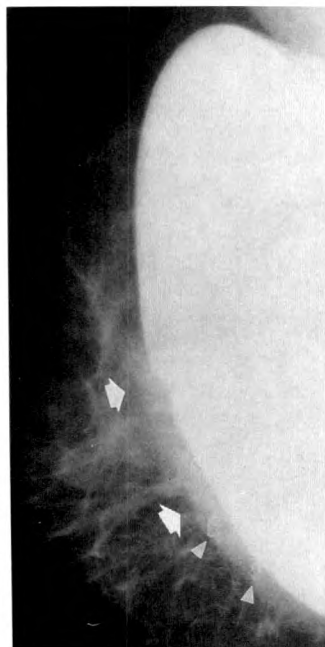
of the vigorous compression used for mammography. Implant rupture may be associated with progression of existing herniation of the sac. The degree of compression used during mammography of an augmented breast is approximately half that used for a nonaugmented breast. Although the compression used during mammography could potentially result in disruption of the fibrous capsule or actual rupture of the implant, an informed consent is not obtained from the patient before the examination is performed. In our practice one patient had sudden softening of one previously firm breast during mammography. However, the patient had a diagnostic mammogram and was not in the study group. The patient underwent implant revision as a result of the difference in the shape of her breasts. At surgery, both implants were intact. To our knowledge, there is no report in the literature of implant rupture incurred as a result of mammography.

Implant failure was shown in 5% of patients, although only seven of the 18 ruptures in five of the 16 patients have been surgically confirmed. This figure of 5% may not accurately reflect the prevalence of implant failure in the asymptomatic population. Factors that may detract from the study as an accurate representation of the asymptomatic women with breast implants include the possibility that these women may have self-selected themselves to have screening mammography. Inquiry as to whether they may have had a history of trauma or closed capsulotomy was not made. Bias from the fact that this is a regional subpopulation may be operative.

The prevalence of implant failure in 5% of patients may be an underestimate of the actual failure rate of breast implants in the women studied. As implant rupture may occur at any point around the periphery of the implant, the radiodense implant may obscure the extravasated silicone. Even when multiple views are available, 100% of the periphery is not visualized. Although it is more likely that larger leaks would be radiographically discernible, a small leak could be obscured, thus resulting in an underestimate of the actual prevalence of failed implants.

Of the three women with mammographic abnormalities who underwent surgical biopsy, carcinoma was found in two cases

Fig. 8.—Mediolateral oblique mammogram of intact subglandular implant in patient with no history of implant revision shows a 5-mm-thick periprosthetic rim of soft tissue (arrows) adjacent to antero-inferior aspect of envelope. Note benign calcifications within pericapsular fibrosis (arrowheads).



and lobular neoplasia (lobular carcinoma in situ) was diagnosed in the third. Of the two cancers, one was stage 0 and the other was stage II.

This study determined the prevalence of certain abnormalities specific to implantation of breast prostheses in asymptomatic women. Women with subglandular implants had a higher rate of sequelae than did women with submuscular implants. Overall, it appears that the submuscular implants offer significant benefits, including improved visualization of the breast parenchyma on mammography.

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The reader's attention is directed to the commentary on this article, which appears on the following pages.

Commentary

Considerations When Imaging Women with Breast Implants

Lawrence W. Bassett^{1,2} and R. James Brenner^{1,3}

Destouet et al. [1] report their experience in the interpretation of screening mammograms obtained in 350 women with breast implants—the largest published series in the literature. This report should be of interest to all radiologists who interpret mammograms. An estimated one to two million women in the United States have undergone augmentation mammoplasty, most of these with silicone gel implants. Complications related to silicone breast implants include fibrous or calcific capsular contracture, rupture and leakage, localized pain, and paresthesias. In addition, it has been reported that silicone gel implants may possibly be associated with the development of generalized autoimmune disorders [2]. Concern about the potential dangers of silicone gel-filled breast implants has reached the Food and Drug Administration (FDA). On April 16, 1992, the agency announced it would allow silicone gel implants to be available only under special conditions [3]. Owing to the desire for implants on the part of patients who have lost a breast because of cancer or trauma, the devices will be available for women enrolled in clinical studies.

Implants and Screening Mammography

Women who have silicone breast implants are not at increased risk for breast cancer [4], but the FDA does recommend that women with implants have screening mammograms at regular guideline intervals, according to age—a

recommendation supported by the American College of Radiology (ACR). Destouet et al. [1] detected two breast cancers among the 350 asymptomatic women they examined.

It is important to emphasize that the examination of women with silicone gel implants requires special expertise by the mammography technologist. For screening mammography of women with silicone gel or saline bag implants, four views, rather than two, should be taken whenever possible. At our facilities, the examination of a patient with implants begins with mediolateral oblique and craniocaudal views of each breast to include as much of the implant and surrounding breast tissue as possible. These views are taken with only moderate compression, intended to hold the breast still, without applying undue force on the implant. Additionally, two "implant-displaced" (modified compression or push-back) views are usually taken, as described by Eklund et al. [5]. These additional views allow for taut compression of breast tissue anterior to the displaced implant. Both implant-included and implant-displaced views are recommended, since either method used alone might result in a cancer being missed. Because the technical requirements are more complex than for a screening examination of a patient without implants, we believe the mammograms should be reviewed for technical quality before the patient leaves the mammography facility. In view of recent media coverage, patients with implants are often anxious at the time of their mammographic examination. For this reason, it is suggested that a radiologist be available to answer questions that the patient may have.

This article is a commentary on the preceding article by Destouet et al.

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Encapsulation of Silicone Gel Implants

As reported in the article by Destouet et al. [1], fibrous tissue encapsulation is a frequent complication of silicone gel breast implants. The capsular membrane that forms around breast implants may be soft and impalpable or hard and resistant. It is uncertain why fibrous encapsulation occurs around implants, but it has been postulated that capsule formation is due to a reaction to silicone droplets diffusing ("bleeding") through the implant envelope or a result of low-grade subclinical infection [6]. When a hard capsule forms, the breast may have an undesirable contour and feel. In addition, a hard, fixed capsule precludes the use of implant-displaced views during mammography. Closed capsulotomy, a procedure by which the surgeon uses vigorous manual compression to disrupt the fibrous capsule, can result in significant herniation of the implant, resulting in mammographic findings that are illustrated in the article by Destouet et al.

Implant Rupture

Rupture implies breakage of the implant envelope that surrounds the silicone gel. Recent unpublished results have suggested an increased prevalence of rupture in patients with silicone gel implants who have undergone closed capsulotomies (De Camara DL et al., presented at the American Society of Plastic and Reconstructive Surgery meeting, September 1991). The potential for rupture of silicone gel implants from mammographic compression is not known. As Destouet et al. indicate, there are no documented cases of rupture due to mammography in the American literature. However, we are aware of unsubstantiated cases of rupture attributed to mammography, including one from an individual radiologic practice listed among a compilation of complications reviewed at a problem case conference [7]. While new, nonimplanted silicone gel bags can withstand considerable compression, it is suspected that over time implanted silicone gel bags may be subject to fatigue and trauma that make them more vulnerable. Therefore, radiologists should at least be aware of the potential for implant rupture during mammography, and should have a protocol within their facilities to deal with any complications that may arise on site. Clinical signs of implant rupture include palpable silicone nodules, decreased breast size, asymmetry, tenderness, and softer texture. It is of interest that Destouet et al. encountered a 5% prevalence of presumed unsuspected silicone extravasation in their patients, suggesting a significant rate of asymptomatic rupture.

Implants surrounded by an intact fibrous capsule can undergo rupture of the implant envelope without leakage into surrounding tissues, resulting in an intracapsular rupture. Manual capsulotomy can convert a contained intracapsular rupture into an extracapsular rupture with leakage of silicone. The fibrous capsule can also break as a result of mammographic compression, an event that may be accompanied by an audible popping sound. Thus, mammographic compression could potentially convert an intracapsular rupture to an extracapsular rupture. If the force from mammographic

compression approaches that of a closed capsulotomy, then new and more difficult questions must be investigated in the discussion regarding the propriety of informed consent.

Informed Consent

The possibility of implant rupture from mammographic compression has led some professional liability carriers to suggest, as a risk management tool, that a signed consent form be obtained prior to mammography of women with breast implants. Radiologists have voiced concern over the need for signed consents as there are few state statutes, regulations, or case laws mandating employment of such a practice, and considerable anxiety could be generated by requiring such consent. Informed consent is generally considered a standard of care issue subject to potential negligence. These standards for disclosure and consent vary from state to state with respect to necessary information required, that is, what a "reasonable physician" should tell a patient, as opposed to what a "reasonable patient" should expect to hear. Such subtle differences have far-reaching implications, and radiologists should be familiar with the parameters used in their own jurisdiction. Leading legal commentary prescribes that the standard of care for any action be related to the probability of an adverse event and the severity of such an event. To the extent that such an adverse event has a reasonable likelihood of occurring, "material" or significant complications should be discussed. Such complications have already been mentioned. The product of probability times severity approaches zero if indeed the probability of such adverse events itself approaches an infinitely small number. Thus, in the absence of documented and reported complications, a general requirement to obtain signed consent forms for the mammographic procedure lacks a compelling indication. No scientific evidence currently available indicates that the appropriate standard of care in imaging patients with silicone breast implants requires the use of signed consent forms. At this time, the ACR does not recommend obtaining consent forms. Instead, attention to technical experience and expertise, as mentioned earlier, should be the focus of attention for the imaging facility.

Other Imaging Techniques

The limitations of mammography in the evaluation of breast implants had led to interest in the use of other imaging techniques for these patients. Harris et al. [8] found sonography to be more sensitive than mammography in the detection of silicone leakage. Of 22 patients with 28 rupture sites, 14 ruptures were missed on physical examination, seven were missed with mammography, and only one was missed with sonography. Our own experience with sonography has not been as rewarding, yet we are convinced that more investigation of the use of sonography is justified, particularly if the results can be correlated with findings at surgical removal. At the University of California, Los Angeles, MR imaging examinations have been performed in 140 symptomatic women with silicone implants. When a combination of pulse se-

quences, including water-suppression techniques, was used, silicone leakage into surrounding breast tissue was identified in approximately 75% of patients with this complication [9].

Conclusions

The subject of silicone implant complications has received so much recent publicity that radiologists are tempted to respond with approaches lacking sufficient scientific documentation. The article by Destouet et al. is an important contribution to the investigations required to develop appropriate understanding of the imaging and natural history of silicone implants.

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Beginning with the January 1993 issue, accepted papers to be published in the *AJR* will be edited and printed by using computer diskettes rather than hard copies of the manuscripts. This change will expedite the editing and publication process and result in less delay between submission of manuscripts and their appearance in the Journal. Also, with the new system, authors will receive page proofs rather than galleys before publication. This will enable them to see exactly what their final article will look like.

Effective immediately, upon acceptance of manuscripts for publication, authors will be asked to send a copy of their revised manuscript on a 3½-in. or 5¼-in. DOS-compatible diskette in WordPerfect or ASCII format along with the hard copy of the revision. Articles will be edited directly on the diskettes. Changes will be highlighted electronically; as before, a hard copy of the edited manuscript and figure proofs will be mailed to authors for approval before publication. Note that hard copies of manuscripts will still be required for the peer-review and revision processes.

The *AJR* already takes great pride in the speed with which the peer-review process is accomplished (mean time, 3.4 weeks) and in the amount of time between submission of manuscripts and their final appearance in print (6 months). This is nearly twice as fast as many other journals. With the new system, these intervals will be even shorter. Authors will see their work in print faster, and the timeliness of the Journal will be greater than ever.

Robert N. Berk
Editor-in-Chief

Meckel's Diverticulum

Felix S. Chew¹ and Domenic A. Zambuto

A 30-year-old woman presented with acute periumbilical abdominal pain and low-grade fever. No β -human chorionic gonadotropin was detected in the serum and the WBC count was 8800/mm³; however, the erythrocyte sedimentation rate was 51 mm/hr. Transvaginal sonography showed a complex mass posterior to the uterus with a target appearance and acoustic shadowing (Fig. 1). The uterus and ovaries were separately identified as normal. Findings on a supine abdominal radiograph were normal. The differential diagnosis included bowel, appendiceal, or tubal lesions containing gas or calcium. At surgery, an inflamed diverticulum containing a fecolith but without perforation was found in the distal ileum. The final pathologic diagnosis was acute diverticulitis in a Meckel's diverticulum.

Meckel's diverticulum is a persistent remnant of the omphalomesenteric duct (vitelline duct), a structure that is normally obliterated by the fifth week of gestation. These structures occur in the distal ileum, about 1 m proximal to the ileocecal valve, usually on the antimesenteric border. Their morphology ranges from a broad-based sacculle to an elongated tubular structure. Heterotopic gastric mucosa is frequently present. Meckel's diverticulum is the most common anomaly of the gastrointestinal tract, with a prevalence of about 2% in the general population [1]. Approximately 22% may be symptomatic; the most frequently treated surgical complications are bleeding from ulceration of the gastric mucosa, obstruction due to intussusception, and inflamma-

tion [2]. The most sensitive methods of radiologic detection are enteroclysis [3] and, if ectopic gastric mucosa is present, ^{99m}Tc-pertechnetate scintigraphy [4].

Acute diverticulitis in a Meckel's diverticulum may develop in a manner similar to idiopathic acute appendicitis. Intraluminal occlusion without compromise of the vascular supply results in acute inflammation that may progress to necrosis and perforation. When the inflammation is confined to the mucosa and submucosa, the gross appearance of the serosal surface shows mildly dilated vessels. With progression of the inflammatory process into and through the muscularis propria, the surface becomes red and hemorrhagic; with further progression, the color darkens and ultimately may become black and gangrenous. Perforation occurs as a late event. This process is different from colonic diverticulitis, in which the diverticula are outpouchings of mucosa and submucosa without a muscularis propria, and perforation occurs early. The treatment is surgical.

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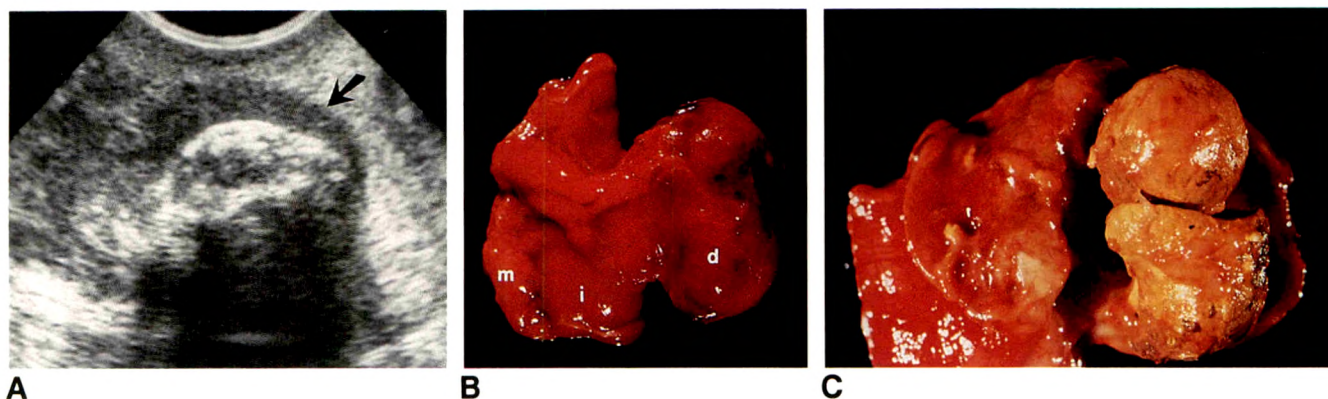


Fig. 1.—Acute diverticulitis in a Meckel's diverticulum.

A, Transvaginal sonogram shows a 3.7 × 2.8 cm rounded lesion (arrow) posterior to the uterus with a hyperechoic, shadowing central region.

B and C, Gross specimen shows an inflamed, hemorrhagic diverticulum, containing a fecolith and extending from the antimesenteric border of the ileum (m = mesentery, i = ileum, d = diverticulum).

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Complications of Continuous Ambulatory Peritoneal Dialysis: Evaluation with CT Peritoneography

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OBJECTIVE. Patients on continuous ambulatory peritoneal dialysis are frequently referred for radiologic evaluation of complications related to the dialysis. We studied the value of CT peritoneography in evaluating these complications. CT peritoneography is a technique in which CT scans are obtained after dialysis fluid containing iodinated contrast material is infused into the peritoneal cavity through the dialysis catheter.

MATERIALS AND METHODS. Sixty consecutive CT studies performed on 48 patients during a 5-year period were retrospectively analyzed. In each case (with two exceptions), the patient had clinical findings suggesting a complication related to peritoneal dialysis. Each study was reviewed for evidence of dialysate leaks, hernias, unopacified fluid collections, and peritoneal adhesions. The patients' medical records also were reviewed to determine the resulting therapy and outcome.

RESULTS. Twenty-nine dialysate leaks were detected on 25 examinations: 15 were along the catheter tunnel, 10 were at the site of a previous surgical incision, two were at a previous catheter site, and two were from an undetermined site (catheter tunnel suspected in both cases). Loculated, unopacified peritoneal fluid collections were present on seven examinations. Adhesions limiting dialysate distribution were shown on five examinations. Five abdominal wall hernias and two inguinal hernias were detected. Overall, at least one abnormality related to continuous ambulatory peritoneal dialysis was shown on 40 (67%) of 60 studies. In 29 (73%) of these cases, clinical management was changed.

CONCLUSION. CT peritoneography is useful for evaluating complications commonly encountered in patients on continuous ambulatory peritoneal dialysis.

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Continuous ambulatory peritoneal dialysis (CAPD) is an established treatment option for patients with end-stage renal disease. This method of dialysis is often chosen instead of hemodialysis in patients in whom vascular access is difficult or in those who have diabetes mellitus or cardiovascular problems [1, 2]. In addition, many patients prefer CAPD because it allows more independence and mobility. However, complications related to this technique are commonly associated with significant morbidity. These can be categorized into complications directly related to the dialysis catheter and those related to the visceral or parietal peritoneum [3-9] (Table 1).

Patients with CAPD-related complications are often referred for radiologic examinations. Although standard body CT is useful, several authors [10-15] have reported that in certain circumstances the CT evaluation of these complications can be improved by infusion of dilute contrast material into the peritoneal cavity before the examination. The role of CT peritoneography in the evaluation of dialysate leaks and in the investigation of abdominal wall and genital edema has been described in previous studies [10-12]. This technique also has been reported to be superior to standard CT in the evaluation of a suspected intraabdominal abscess [13-15].

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TABLE 1: Complications Related to Continuous Ambulatory Peritoneal Dialysis

Related to Catheter	Related to Peritoneum
Tunnel leak or pseudohernia	Acute peritonitis
Drainage failure	Leakage of dialysis fluid
Infection of exit site or tunnel	Adhesions
Catheter migration	Intraabdominal abscess
Subcutaneous catheter kinking	Abdominal wall and inguinal hernias
Severing of external catheter segment	Sclerosing peritonitis

The purpose of this study was to address the usefulness of CT peritoneography in the evaluation of a large series of patients with a variety of CAPD-related problems.

Materials and Methods

We retrospectively analyzed 60 consecutive CT peritoneograms obtained in 48 patients being treated with CAPD between April 1986 and May 1991. The patients included 25 males and 23 females, ranging from 6 to 76 years old (mean, 38 years). At the time of examination, the duration of the patients' treatment with CAPD ranged from 2 weeks to 76 months (mean, 28 months).

The reasons for referral of patients were categorized to reflect the primary indications for CT peritoneography; 15 patients had clinical findings belonging to more than one category. Twenty-five patients had fever, leukocytosis, or persistent peritonitis and were referred for CT peritoneography to exclude an intraabdominal abscess. Twenty-three patients were referred because of difficulty with the exchange of dialysis fluid, usually poor drainage. Other common CAPD-related problems resulting in referral for CT peritoneography included abdominal wall and/or genital edema (12 patients), abdominal pain with no signs of infection (six patients), dialysate leak (five patients), and suspected hernia (four patients).

Two patients had clinical findings that did not fit into one of the categories listed. One had pancreatitis, and CT peritoneography was performed to exclude a concomitant intraperitoneal process. The other patient was referred for the evaluation of cirrhosis and portal hypertension. CT peritoneography was requested instead of standard CT, although the clinical findings did not suggest a CAPD-related complication.

CT peritoneography was performed by adding 50 ml of 60% meglumine diatrizoate (Winthrop, New York, NY) to each liter of dialysis fluid. For each patient, an appropriate volume was administered 1 hr before scanning. Outpatients were given the mixture of contrast material and dialysis fluid in the radiology department and were encouraged to walk before imaging was done. Inpatients generally had the mixture added by the nursing staff or house staff before arriving in the radiology department. No patient had adverse effects related to the intraperitoneal infusion of dilute contrast material. Oral contrast material was used in 41 (68%) of 60 studies and IV contrast material in seven (12%). A GE 9800 CT/T scanner was used for all patients, and axial 10-mm-thick contiguous sections through the abdomen and pelvis were obtained. The scan time was 2 sec, with an interscan delay of 6 sec.

The studies were retrospectively reviewed by a panel of three radiologists who did not know the patients' clinical history or outcome. They looked for evidence of the following CAPD-associated complications: dialysate leaks, loculated fluid collections, hernias, and peritoneal adhesions suggested by the poor intraperitoneal distribution of dialysis fluid. After a consensus was reached, the original interpretation was verified. The patients' clinical records were reviewed and the data confirmed by the attending nephrologist. The clinical indications for each examination, the subsequent therapy, and outcome after each examination were recorded.

Results

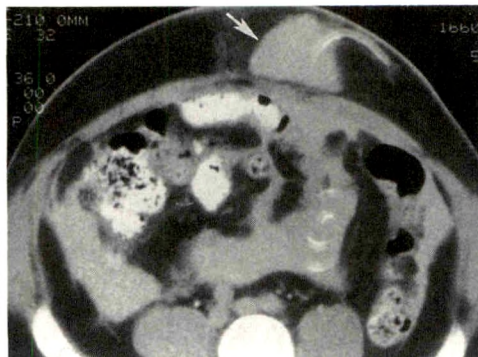
Forty (67%) of the 60 CT peritoneograms obtained in this series showed at least one CAPD-related abnormality. Clinical management was affected in 29 (73%) of these cases, including the use of surgical intervention.

Dialysate Leaks

The most frequent finding was a dialysate leak; 29 leaks were detected on 25 CT peritoneograms (four examinations had two distinct leaks). Fifteen of the leaks were found along the catheter tunnel (Figs. 1 and 2). On two examinations, CT peritoneography showed subcutaneous infiltration of dialysate in the region of the catheter but did not clearly show that the leak originated from the catheter tunnel. A leak was detected at the site of a previous surgical incision on 10 examinations and at an old catheter site on two (Fig. 3).



1



2

Fig. 1.—Dialysate leak. 29-year-old woman with external leakage of dialysate. CT peritoneogram shows site of extravasation is along catheter tunnel. Note nonfunctioning transplanted kidney (TK) in left lower quadrant.

Fig. 2.—Contained dialysate leak. 46-year-old man with palpable abdominal wall mass (suspected hernia) and difficulty with dialysis fluid exchanges. CT peritoneogram shows contained leakage of dialysate along catheter tunnel (arrow), which resulted in poor dialysis function and palpable mass.



Fig. 3.—Leakage of dialysate at site of previous surgical incision. 31-year-old man with abdominal pain and difficulty with dialysis fluid exchanges. CT peritoneogram shows leakage of dialysate at site of previous surgical incision rather than adjacent catheter tunnel (arrow). There is extensive infiltration of dialysate enhanced with contrast material into subcutaneous fat adjacent to leak.

In most cases, a leak shown by CT peritoneography was only indirectly suggested by the clinical findings. A leak was the cause of poor drainage of dialysate in 11 patients and the cause of abdominal wall or genital edema in nine patients. Two of the patients with poor drainage of dialysate and one of the patients with abdominal wall edema also had unexplained abdominal pain with no signs of infection. A confined leak along the catheter tunnel (pseudohernia) was found in two patients in whom an abdominal wall hernia had been

suspected on the basis of clinical findings (Fig. 2). A third patient referred for evaluation of a presumed abdominal wall hernia had an incisional leak.

CT peritoneography was performed for the evaluation of external leakage of dialysate in five cases. In four of these, the site of the leak was detected. In the fifth case, a leak from the catheter tunnel was presumed because of the detection of dialysate enhanced with contrast material infiltrating the subcutaneous tissues adjacent to the catheter. Finally, small and asymptomatic leaks were discovered incidentally on six CT peritoneograms.

Five of the 15 patients in whom CT peritoneography showed a leak from the catheter tunnel had prompt surgical replacement of the catheter. In addition, five of the 12 patients who had a leak at the site of a previous surgical incision or a previous catheter site required surgical repair so that CAPD could be resumed. Nine patients with tolerable symptoms and adequate dialysis function were treated by temporarily switching the method of dialysis to either hemodialysis or automated peritoneal dialysis. The six patients with asymptomatic pericatheter or incisional leaks did not require therapy for the leak.

Loculated Fluid Collections

Unopacified fluid collections in the peritoneal cavity were seen on seven CT peritoneograms. In one case, surgery showed that an unenhanced fluid collection in the lesser sac was an abscess. In another case, CT peritoneography

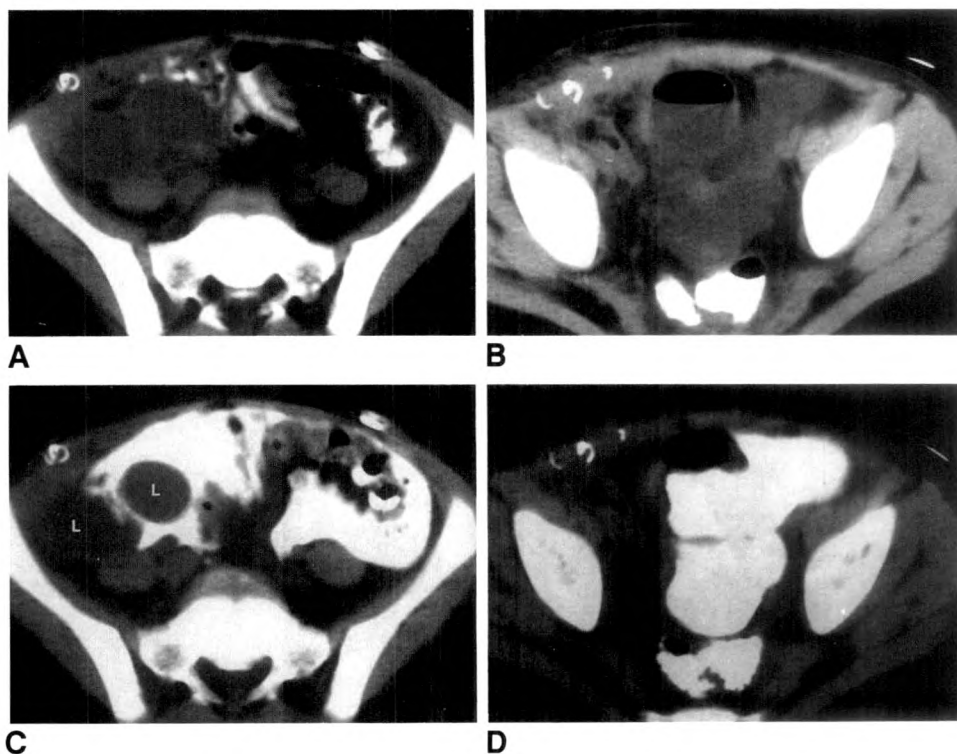


Fig. 4.—Loculated fluid collections. 10-year-old girl with gangrenous, perforated gallbladder and biliary peritonitis.

A and B, Standard CT scans show suspicious fluid collections in right lower quadrant and pelvis.

C and D, CT peritoneograms obtained after standard CT show fluid collections in right lower quadrant are loculated (L). However, pelvic fluid enhances completely, thereby excluding another abscess in this location.

showed multiple intramesenteric fluid collections in the right lower quadrant that did not opacify after infusion of dilute contrast material into the peritoneal cavity (Fig. 4). Exploratory laparotomy revealed a perforated, gangrenous gallbladder and biliary peritonitis. In a third case, an unopacified pelvic fluid collection was aspirated with CT guidance. However, the results indicated that the fluid was sterile. In four remaining cases, the suspicious fluid collections were small. As a result, these patients were treated with intraperitoneal antibiotics and followed up clinically.

In each of the seven cases in which an unopacified fluid collection was detected, an abscess had been suspected on the basis of the clinical findings (i.e., fever, leukocytosis, or recurrent peritonitis). In the remaining 18 cases referred because of a suspected abscess, the distribution of contrast-enhanced dialysis fluid throughout the peritoneal space (including the opacification of residual dialysate from the previous dialysis exchange) allowed an intraabdominal abscess to be confidently excluded.

Hernias

Five abdominal wall hernias (three ventral, one epigastric, and one spigelian) and two inguinal hernias were detected. In one child, a recurrent right-sided inguinal hernia was suspected and was confirmed with CT peritoneography before a second herniorrhaphy was done. Another patient was referred because of penile and scrotal swelling that extended to the lower abdominal wall. CT peritoneography showed a patent left processus vaginalis, and a small leak extending from the inguinal canal into the subcutaneous tissues of the lower abdominal wall (Fig. 5). Surgical repair of the inguinal hernia eliminated the genital swelling and the edema in the lower abdominal wall.

In one patient referred after several weeks of unexplained abdominal pain and fever, a ventral hernia was diagnosed on the basis of findings on CT peritoneography. At surgery, a hernial sac with an incarcerated loop of small bowel was found. Another ventral hernia was found in a patient having difficulty with the exchange of dialysis fluid. A concomitant catheter tunnel leak also was found. The patient did well after elective repair of the hernia and replacement of the dialysis catheter. A third incidentally discovered ventral hernia was

small and was successfully treated by temporarily switching the method of dialysis to automated peritoneal dialysis.

The patient with the spigelian hernia had difficulty with dialysis because of significant peritoneal adhesions. As a result, CAPD was discontinued without surgical repair of the hernia. The epigastric hernia was found incidentally in a patient who had abdominal pain and leukocytosis. This patient had infarcted small bowel (unrelated to the hernia) and died of sepsis.

Peritoneal Adhesions

The presence of intraabdominal adhesions was suggested by findings on CT peritoneography in five cases because the distribution of enhanced dialysis fluid was poor. In each case, the patient had had at least one preceding episode of severe peritonitis and was referred because of difficulty with the exchange of dialysis fluid. In four cases, the patient had a previous episode of *Staphylococcus aureus* or fungal (*Candida albicans* or *Penicillium* species) peritonitis, and in the fifth case, the patient had a history of chemical peritonitis (Fig. 6). One of the five patients was able to resume CAPD after surgery for lysis of adhesions and replacement of the dialysis catheter. In the four remaining cases CAPD was permanently discontinued. In three of these four, the method of dialysis was switched to hemodialysis. Hemodialysis was not technically possible in the fourth case, and dialysis, along with other medical management, was stopped.

Normal Studies

Twenty studies did not show any abnormalities related to CAPD. Six of these studies were done because the patient had difficulty with the exchange of dialysis fluid. In each of these cases, CAPD was successfully resumed after catheter replacement. Surgical findings in three of the six cases included fibrinous obstruction of the catheter lumen, catheter encasement by adhesions, and omental wrapping of the catheter. In the remaining three cases, no specific cause for the poor exchange of dialysis fluid was determined.

In 11 of the 20 cases, CT peritoneography was performed to exclude an intraabdominal abscess. In four of these cases,

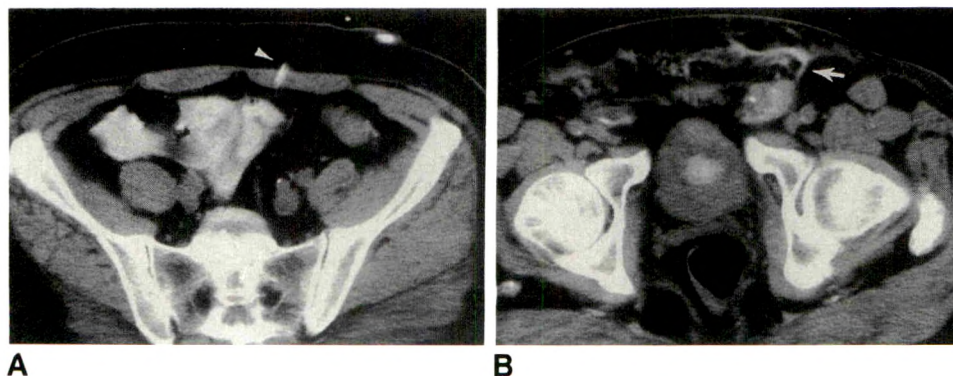


Fig. 5.—Inguinal hernia. 46-year-old man with lower abdominal wall and genital edema.

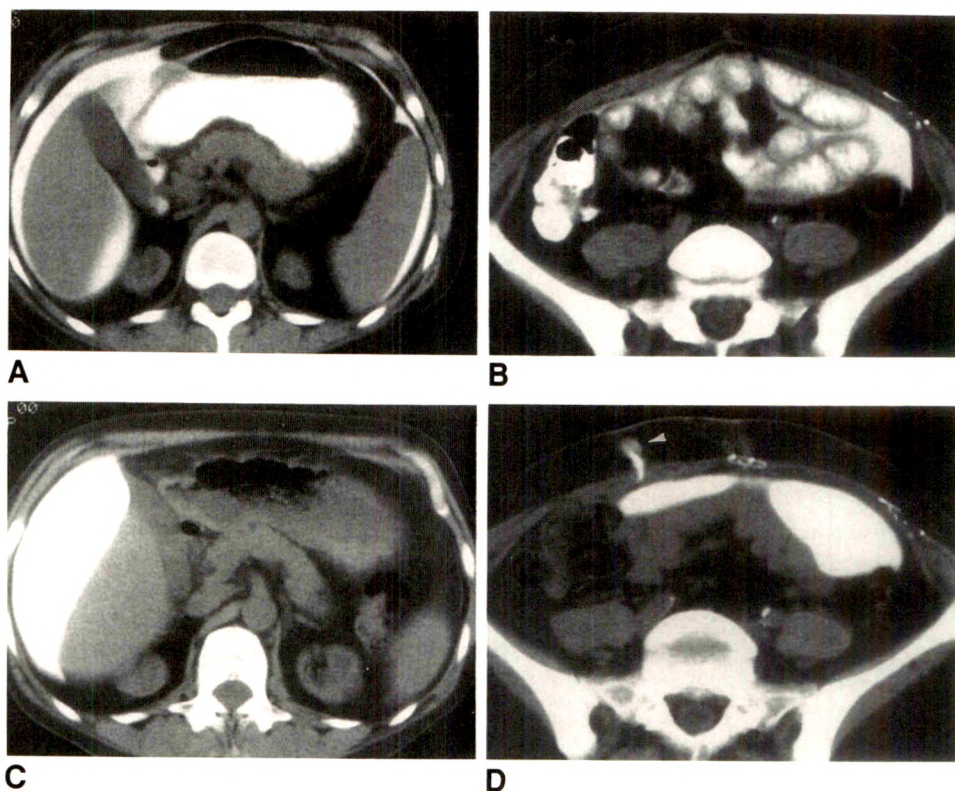
A, CT peritoneogram shows a normal catheter site (arrowhead).

B, More caudal section from same CT peritoneogram shows a patent processus vaginalis and leak (arrow) extending from inguinal canal into subcutaneous tissues of lower abdominal wall.

Fig. 6.—Peritoneal adhesions. 38-year-old woman who initially presented with abdominal pain after an episode of chemical peritonitis and returned 4 months later having difficulty with dialysis.

A and B, Initial CT peritoneograms show normal distribution of dialysis fluid.

C and D, CT peritoneograms obtained 4 months after A and B show loculation of dialysis fluid enhanced with contrast material in right perihepatic space. Hepatorenal and perisplenic spaces are no longer opacified. Loculation of dialysis fluid is seen anteriorly in abdomen (D). Intramesenteric distribution of dialysis fluid is no longer seen. Note a small dialysate leak (arrowhead) along catheter tunnel.



infection of the catheter tunnel was presumed, and in each of these cases the catheter was replaced with good results.

CT peritoneography did not show any CAPD-related abnormalities in two patients with unexplained abdominal pain. One patient had a subsequent exploratory laparotomy, which showed minor adhesions. In the other case, the cause of the pain remained undetermined. The final CT peritoneogram that did not show any CAPD-related abnormality was a routine examination for the evaluation of cirrhosis and portal hypertension.

Discussion

CAPD is a common alternative to hemodialysis for patients with end-stage renal disease. It is estimated that 15,000 patients in the United States and more than 35,000 worldwide are being treated with CAPD [16]. At our institution, more than 200 patients have used this method of dialysis during the past 5 years, with an average of approximately 100 patients being treated with CAPD at any given time.

The most common complication of CAPD is acute peritonitis, in most series occurring with an incidence of approximately one case per patient per year. These episodes usually resolve with intraperitoneal administration of antibiotics without interruption of dialysis [7]. Numerous other complications related to this method of dialysis have been described [3–6, 8, 9]. Often the clinical findings are complex, and the patient is referred for radiologic examination.

Twardowski et al. [10] originally proposed that the CT evaluation of patients on CAPD could be improved by infusing a mixture of contrast material and dialysis fluid before scans were obtained. CT peritoneography has several potential advantages over standard CT. Loculated fluid collections can be more readily distinguished from adjacent dialysate in the peritoneum. In addition, the site and pathway of leakage of dialysis fluid can be detected. This is particularly important in the evaluation of abdominal wall swelling, which may be due to an inflammatory process, subcutaneous extravasation of leaked dialysate, or an abdominal wall hernia. Finally, with CT peritoneography, the distribution of dialysis fluid in the peritoneal space can be assessed in cases in which adhesions are suspected.

Extraperitoneal leakage of dialysate is a common problem in patients having peritoneal dialysis. Leakage may result in open extravasation of dialysate or, more commonly, abdominal wall edema from infiltration of the fluid into the subcutaneous tissues. Either process can cause inadequate drainage of dialysate with a positive fluid balance [10]. Extravasation of dialysate is particularly common when the leak occurs along the catheter tunnel, and this also has been associated with an increased risk for peritonitis [17]. Numerous catheter designs and surgical techniques have been used in attempts to reduce the prevalence of this problem [4, 17–20].

The catheter tunnel was the most common source of leakage of dialysate in our series. In most cases, the leaks were readily shown by CT peritoneography (Fig. 1). We also observed that several of these leaks were confined to a short

extraperitoneal segment of the catheter tunnel, resulting in a palpable mass (pseudohernia, Fig. 2). Sites of previous surgical incisions also have been implicated in both external leakage and subcutaneous leakage resulting in abdominal wall edema [2]. External and subcutaneous leakage at catheter and surgical sites is related to the chronically increased abdominal pressure associated with CAPD. Many of the patients in our series had had multiple surgical procedures, including catheter replacement, renal transplantation, and transplant nephrectomy.

Whatever the cause, small leaks are sometimes managed conservatively by temporarily discontinuing CAPD; automated peritoneal dialysis or hemodialysis is used in the interim [11]. Automated peritoneal dialysis uses more frequent exchanges and smaller volumes than CAPD does and produces less increased intraabdominal pressure. However, if a leak is symptomatic or results in inadequate dialysis, surgical repair or replacement of the catheter is often necessary. In these cases, precise localization of the site of the leak is important for planning appropriate surgical treatment.

Frequently, patients on CAPD who have persistent abdominal pain, fever, leukocytosis, or recurrent peritonitis are referred for CT examination to exclude an occult intraabdominal abscess. Evaluation with standard CT can be difficult. If the examination is performed after drainage of the patient's dialysate, a residual fluid collection may be suggestive of an abscess. This is particularly a problem in nonambulatory patients in whom the drainage is likely to be incomplete. If possible, scanning again with the patient in a different position (e.g., prone) may be helpful. CT peritoneography makes this evaluation less of a problem. An intraabdominal abscess can be more confidently excluded if CT peritoneography shows complete enhancement of the intraperitoneal fluid. In the appropriate clinical setting, an unenhanced fluid collection suggests an intraabdominal abscess.

Abdominal wall and inguinal hernias are frequent complications of CAPD [9, 21–23]. Previously asymptomatic hernias are often exacerbated by CAPD, so detectable hernias are usually repaired before dialysis is started [4, 5, 24, 25]. Except in obese patients, most abdominal wall hernias are palpable. These hernias also are likely to be detected on standard CT. However, in our series, several patients who had a palpable abdominal wall mass and were suspected of having a hernia had a confined leak instead. This suggests that CT peritoneography can provide a more complete evaluation than standard CT in these cases.

Occasionally, genital swelling occurs without a palpable inguinal hernia [26, 27]. In addition, several investigators [4, 11, 12] have reported leakage of dialysate along the fascial planes of the abdomen extending into the scrotum, resulting in genital edema mimicking an inguinal hernia. Recognition of patients in this group is important in order to avoid unnecessary herniorrhaphy. Although the number of patients referred for evaluation of genital swelling in this series was small, we were able to determine the cause in each case by using CT peritoneography. An additional finding was the subcutaneous leakage of enhanced dialysis fluid from the inguinal canal in one patient with a patent processus vaginalis. We have noted

this finding in another case since the completion of our series. This suggests that the peritoneum of the inguinal canal is permeable when stretched and that the genital edema associated with an inguinal hernia may be due to extravasation of dialysate by this route.

Significant adhesions, which can limit the adequate intra-peritoneal distribution of dialysis fluid, were readily detected on CT peritoneograms. Only one patient in this group was able to continue CAPD after replacement of the dialysis catheter and extensive lysis of adhesions. CT peritoneography was not effective in showing fibrinous obstruction of a catheter, encasement of a catheter by adhesions, or obstruction of a catheter by omental wrapping. However, this does not diminish the role of CT peritoneography in patients in whom the exchange of dialysis fluid is inadequate. Knowledge of peritoneal adhesions, an abdominal wall hernia, or leakage of dialysate from a site other than the catheter tunnel is valuable preoperative information. In these cases, catheter replacement alone is unlikely to result in complete resolution of the problems with dialysis.

In summary, we investigated the role of CT peritoneography in the evaluation of a large series of patients on CAPD who had a variety of common problems related to this method of dialysis. We found that CT peritoneography is particularly useful for localizing leakage of dialysis fluid and evaluating for suspected occult intraabdominal abscess. CT peritoneography also has a role in the investigation of a suspected abdominal wall or inguinal hernia and is often useful in the examination of patients who are having difficulty with the exchange of dialysis fluid. In this series, the findings on CT peritoneography affected clinical management (including surgical intervention) in 73% of 40 cases with CAPD-related findings. We conclude that CT peritoneography is a useful examination in the evaluation of CAPD-related complications.

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Book Review

Introduction to Abdominal Ultrasonography. By Y. Higashi, A. Mizushima, and H. Matsumoto. New York: Springer-Verlag, 215 pp., 1991. \$59

In the preface, the authors clearly state that this textbook is intended for "medical students, residents in diagnostic radiology, and ultrasonologists who have just begun detailed studies in ultrasound diagnosis." The authors take nothing for granted: The first chapter is on the principles of ultrasound, and the second is on scanning techniques and anatomy. The ensuing chapters follow an organ-oriented approach and systematically discuss sonography of the abdomen. They deal with liver, gallbladder and bile ducts, pancreas, spleen, kidneys, adrenal glands, retroperitoneum, and miscellaneous topics. The book concludes by giving a glossary of terms and numerous exercises aimed at testing the readers' understanding of the subject matter.

The chapter on principles of ultrasound is a relatively simple introduction, although at times, references are made to physical principles and phenomena that have not been previously discussed or elucidated. Many of these terms, however, are defined in the glossary. The chapter on the liver begins with an extensive discussion of hepatic vascular and segmental anatomy. Numerous color diagrams have been included, and although they are somewhat confusing initially, with careful thought by the reader, they add to the understanding of hepatic anatomy. In the discussion of focal hepatic lesions, the authors refer to Snell's law; however, this law is not further defined either in this chapter or in the glossary. The chapter has no discussion of cystic metastases and their appearance, and no reference is made to the increased through-transmission associated with many cavernous hemangiomas. The discussion of polycystic liver disease is disappointing. The authors state that sonography is more sensitive than CT for detecting fatty infiltration of the liver. This is doubtful.

In the chapter on the gallbladder and bile ducts, the discussion of

acute cholecystitis is not only incomplete but also somewhat misleading in terms of sensitivity and specificity. The authors use the abbreviation TAE, which I assume means transarterial embolization, although this term is never defined, either in the text or in the glossary. In the chapter on the pancreas, the authors use the terms "mass" and "tumor" interchangeably, whether the entity they are discussing is malignant or inflammatory. I found this nomenclature somewhat confusing. In the chapter on the kidney, the discussion on urinary tract duplication and associated ectopic ureterocele is cursory. The chapter on miscellaneous topics has no discussion of the use of sonography for diagnosis of appendicitis.

In general, the sonograms are of excellent quality; particularly the real-time images. The book is consistent in using images that are black on white. However, I was surprised to notice that the gain settings on several of the examples were improper and a poor example for new sonographers. The diagrams are excellent, although somewhat optimistic at times about what is being shown on the corresponding image. The CT scans are poor; most were obtained with low-resolution scanners, often without contrast enhancement.

I am considerably bothered that the book has no references at all. In my opinion, this is a major oversight that detracts from the overall value of this text. In conclusion, I think that this textbook is an excellent introduction for a beginning sonographer, whether physician or technologist. It presents a reasonable discussion of the strengths and weaknesses of ultrasound as a tool for diagnostic imaging of the abdomen.

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Percutaneous Obliteration of the Cystic Duct with a Holmium:Yttrium-Aluminum-Garnet Laser: Results of In Vitro and Animal Experiments

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OBJECTIVE. The purpose of this study was to investigate the feasibility of using a holmium:yttrium-aluminum-garnet laser to permanently occlude the cystic duct in order to isolate the gallbladder from the biliary-enteric circulation and prevent gallstone formation.

MATERIALS AND METHODS. To determine the optimal laser parameters (power and pulsing rate) for cystic duct thermocoagulation, 20 freshly excised porcine gallbladders with intact cystic ducts underwent low-energy (0.075–0.085 J/pulse) or high-energy (0.20–0.25 J/pulse) thermocoagulation. Histopathologic examination was done to determine the extent of cystic duct injury. After in vitro experiments, percutaneous transcholecystic laser thermocoagulation of the cystic duct was performed on 23 anesthetized domestic pigs (four controls). Cholangiograms immediately after laser thermocoagulation were obtained to assess cystic duct occlusion. Animals were sacrificed for histopathologic correlation immediately after laser thermocoagulation ($n = 4$), 72 hr later ($n = 4$), and 6 weeks later ($n = 15$).

RESULTS. In the in vitro studies, all 10 cystic ducts in the high-energy group were occluded, while only four in the low-energy group were occluded. At histology, all cases in both groups showed circumferential injury to the cystic duct wall without injury to the cystic artery or vein. In the in vitro experiments, the cystic duct was successfully cannulated in 21 (91%) of 23 animals. Cholangiography after thermocoagulation showed occlusion of the cystic duct in 16 (84%) of 19 cases. Immediately after laser thermocoagulation, the cystic duct mucosa was circumferentially destroyed, whereas after 72 hr necrosis of the cystic duct wall and periductal tissues had occurred. By 6 weeks, all pigs had complete cystic duct fibrosis without injury to the common bile duct.

CONCLUSION. Holmium:yttrium-aluminum-garnet laser thermocoagulation of the cystic duct can be performed easily, results in immediate cystic duct occlusion, and leads to permanent fibrous ductal obliteration by 6 weeks.

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The availability of nonsurgical techniques for the treatment of gallstone disease [1–14], especially in patients for whom surgical risks are high, has spurred interest in the development of alternative strategies for the prevention of recurrent cholelithiasis [15, 16]. The fundamental objective has been to devise a method that can permanently occlude the cystic duct and thereby isolate the gallbladder from the biliary-enteric circulation and prevent gallstone formation. Initial percutaneous attempts at cystic duct occlusion were based on angiographic embolization techniques with materials such as gelatin sponges, metal coils, and tissue adhesive plugs [17–19]. These experiments, however, failed to produce long-term occlusion of the cystic duct [19]. In 1988, Becker et al. [19] were the first to report permanent fibrous occlusion of the cystic duct. Working with a pig model (with results subsequently reproduced in eight patients), they demonstrated fibrotic scarring and obliteration of the cystic duct after superficial thermal injury from an endoluminal RF electrocoagulation probe [19–22]. RF electrocoagulation results in tissue heat-

ing, which leads to protein denaturation, thermocoagulation, and eventually fibrosis [23, 24].

Similar to RF electrocoagulation, laser energy heats tissues to cause thermocoagulation and eventual fibrosis [23, 24]. Laser systems have very small delivery mechanisms, thereby allowing the use of small percutaneous catheters and the creation of long-segment occlusions that may be less likely to recanalize. The purpose of this study was to perform *in vitro* and animal experiments to ascertain the feasibility of using a holmium:yttrium-aluminum-garnet (YAG) laser to occlude the cystic duct percutaneously.

Materials and Methods

In Vitro Experiments

To determine the optimal laser parameters (power and pulsing rate) for cystic duct thermocoagulation, we performed preliminary *in vitro* experiments. Twenty freshly excised gallbladders with intact cystic ducts were obtained from a domestic pig farm. Direct injection cholecystography (Urovis 14%, Berlex Laboratories, Wayne, NJ) was done to determine the caliber of the cystic duct and to measure the volume of contrast material needed to opacify the cystic duct. Under direct vision, the cystic ducts were then cannulated in a retrograde fashion with the holmium:YAG fiber (0.6-mm diameter). Ten specimens underwent low-energy laser thermocoagulation with a pulse repetition rate of 10 pulses/sec and a power setting of 0.75–0.85 W (0.075–0.085 J/pulse). Ten specimens underwent high-energy laser thermocoagulation at 10 pulses/sec and 2.0–2.5 W (0.20–0.25 J/pulse). In both groups, the laser fiber was withdrawn along the entire length of the cystic duct at a rate of 5 mm/sec. Immediately after laser thermocoagulation of the entire cystic duct, the gallbladder was punctured with a 22-gauge needle and a contrast cholecystogram was obtained to determine cystic duct occlusion. Contrast material (Urovis 14%) was injected until either the cystic duct was visualized or the gallbladder burst (indicating occlusion of the cystic duct). The volume of contrast material needed to opacify the cystic duct or rupture the gallbladder was recorded. All specimens were later histopathologically examined by an experienced pathologist to determine the extent of injury to the cystic duct.

In Vivo Experiments

In vivo experiments were done to determine the efficacy of laser energy in producing long-term obliteration of the cystic duct. Experiments were performed in fasting pigs that were sedated (intramuscular ketamine hydrochloride and xylazine hydrochloride) and under mask general anesthesia (halothane). National Institutes of Health guidelines for the care of laboratory animals were followed. Twenty-three female domestic pigs underwent successful percutaneous transhepatic cholecystostomy. With sonographic and fluoroscopic guidance, an 18-gauge sheath needle was inserted percutaneously into the gallbladder via a transhepatic route. Aspiration of bile and injection of contrast material confirmed an intraluminal position. A 0.035-in. (0.089-cm) guidewire (Terumo, Medi-Tech, Watertown, MA) was then inserted and coiled in the gallbladder. By means of the Seldinger technique, a 5-French dilator (Cook, Bloomington, IN) with multiple side holes was positioned in the gallbladder. A cholecystogram was obtained to determine the volume of the gallbladder and to define the origin and course of the cystic duct. Under fluoroscopic guidance, the cystic duct was cannulated with the guidewire, over which the 5-French catheter was advanced to the junction of the cystic duct and the common bile duct. The cystic duct was success-

fully cannulated in 21 (91%) of 23 animals. In one case, a guidewire could not be manipulated into the cystic duct despite multiple attempts. This animal served as a control for the group of pigs that was sacrificed immediately after laser thermocoagulation. In the other case, a guidewire was easily inserted into the cystic duct; however, the 5-French catheter could not be manipulated into the cystic duct. This animal served as a control for the group of pigs that was sacrificed after 72 hr. Two additional pigs who served as controls underwent cystic duct cannulation without delivery of laser energy. Thus, 19 animals underwent laser thermocoagulation.

The holmium:YAG laser fiber (similar to a guidewire) was delivered through the 5-French catheter so that its tip protruded 2 mm beyond the tip of the catheter. Laser thermocoagulation of the entire cystic duct was accomplished with a pulsing rate of 10 pulses/sec and a power setting of 2.0–2.5 W (0.20–0.25 J/pulse) while withdrawing both the catheter and laser fiber together at a rate of 5 mm/sec. These parameters are identical to those used in the high-energy *in vitro* study group. A contrast-enhanced cholecystogram through the catheter was obtained after thermocoagulation to determine if immediate occlusion of the cystic duct occurred. The volume of contrast material injected was twice the gallbladder volume determined with the prethermocoagulation cholecystogram. In those pigs who did not undergo subsequent gallbladder sclerotherapy, the gallbladder was irrigated with saline and the catheter was removed.

Histopathologic Correlation

Histopathologic correlation was performed in all animals. Four animals (including one control) were sacrificed immediately after laser thermocoagulation, four (one control), 72 hr later, and 15 (two controls) 6 weeks later. Ten pigs in the 6-week group who underwent cystic duct laser thermocoagulation also underwent gallbladder sclerotherapy, which we describe in a companion article [25]. The liver, gallbladder, cystic duct, common bile duct, and duodenum were resected en bloc and fixed in formalin. Multiple sections through the cystic duct and gallbladder that included the adjacent liver and the common bile duct were obtained and stained with hematoxylin and eosin for microscopic examination by an experienced pathologist.

Results

In Vitro Experiments

The average number of pulses per centimeter of cystic duct length was similar for both the low-energy (140 ± 40) and the high-energy (132 ± 67) groups (Table 1). Gross perforation or extravasation at cholecystography did not occur in either group.

In the high-energy group, all 10 cystic ducts were occluded, as determined by direct-injection cholecystography. In the low-energy group, four of 10 cystic ducts were occluded, while an additional four were narrowed but not occluded. The remaining two were patent and unchanged in caliber. The burst volumes for the 10 occluded cystic ducts in the high-energy group and the four in the low-energy group were similar, 18.8 ± 5.4 ml vs 18.4 ± 5.1 ml, respectively. The volumes required to opacify the cystic duct in the narrowed (four) and patent (two) groups were 15.0 ± 5.6 ml and 10.0 ± 7.1 ml, respectively (Table 1); the preablation volume required to opacify the cystic ducts was 8.6 ± 6.9 ml.

At histology, circumferential injury to the cystic duct was found in all cases in both groups. The extent of thermocoa-

TABLE 1: In Vitro Results of Laser Thermocoagulation of Porcine Cystic Ducts

Finding	Type of Thermocoagulation	
	High Energy (n = 10)	Low Energy (n = 10)
Prethermocoagulation volume of contrast material required to opacify cystic duct (ml)	9.1 ± 6.1	8.6 ± 6.9
Average no. of laser pulses/cm cystic duct length	132 ± 67	140 ± 40
Cholangiographic findings after laser thermocoagulation of the cystic duct		
No. occluded	10	4
Rupture volume of gallbladder (ml)	18.8 ± 5.4	18.4 ± 5.1
No. narrow but patent	0	4
Volume of contrast material needed to opacify cystic duct (ml)		15.0 ± 5.6
No. patent	0	2
Volume to opacify cystic duct (ml)		10.0 ± 7.1

gulation was full thickness in all cases in the high-energy group and in four of 10 cases in the low-energy group. The thermal effect was confined to the pericystic duct tissues and remote from the cystic artery and/or vein in six of 10 cases in the high-energy group and in eight of 10 cases in the low-energy group. In the remaining cases in both groups, the thermal effect extended to but did not show injury of the cystic artery or vein. In these cases, inflammatory cells were present along the edge of the vessel but not within the vessel wall.

In Vivo Experiments

Of the 19 animals who underwent laser thermocoagulation, cholangiography showed immediate occlusion of the cystic duct in 16 (84%) and segmental filling or narrowing in three (16%) (Fig. 1). The average number of laser pulses per centimeter of cystic duct length was 127 ± 53 . The prether-

mocoagulation volume of contrast material required to opacify the cystic duct was 8.9 ± 5.9 ml in the control group and 9.0 ± 5.6 ml in the study group. The postthermocoagulation contrast volume required to opacify the narrowed cystic ducts was 15.4 ± 3.6 ml, while the average volume of contrast material injected into the gallbladders with occluded cystic ducts was 17.7 ± 2.1 ml. One cystic duct in the occlusion group was perforated in the midportion of the duct. The perforation was thought to have been caused by withdrawing the laser fiber too slowly, thus fusing the laser fiber to the cystic duct wall and resulting in both increased focal thermal injury and mechanical trauma when the laser fiber was withdrawn. The perforation was isolated by a second pass of laser thermocoagulation distal (on the gallbladder side) to the perforation, and complete fluoroscopic obliteration was achieved. This animal had no adverse side effects. In no cases was there evidence of coagulated tissue adherent to the tip of the laser fiber at the conclusion of the laser thermocoagulation.

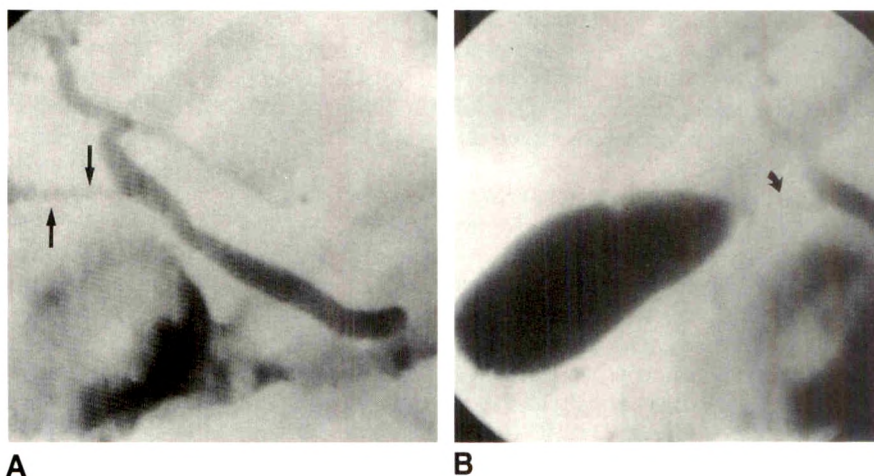
One group of animals (three treated, one control) was sacrificed immediately after laser thermocoagulation. At histology, all three treated animals had circumferential destruction of the mucosa of the entire cystic duct. Despite the apparent immediate occlusion at cholangiography, the cystic duct lumen was narrowed but patent (Figs. 2A and 2B). In the 72-hr group, necrosis of the cystic duct wall and periductal tissues had occurred. The narrowed lumen of the cystic duct was occluded by intraluminal debris (Fig. 2C). In the 6-week group, all treated pigs had complete fibrosis of the entire cystic duct (Fig. 2D). This excludes two animals early in our experience who died 5 and 12 days, respectively, after thermocoagulation of uncertain causes. Autopsy showed no bile peritonitis or gallbladder necrosis in these cases. The three animals with the narrowed cystic ducts at cholangiography immediately after thermocoagulation were included in the 6-week group, and complete cystic duct fibrosis identical to that in pigs with immediate cystic duct occlusion was seen.

In 11 (58%) of 19 animals, the thermal effect extended to include the cystic artery and/or vein (inflammatory cells present in the vessel wall); however, in all animals who underwent laser thermocoagulation and were sacrificed 6 weeks later,

Fig. 1.—Thermocoagulation of cystic duct in a pig model.

A. Cholangiogram shows free flow of contrast material through patent cystic duct (arrows) into common bile duct.

B. Cholecystogram after laser thermocoagulation shows immediate occlusion of cystic duct (arrow). Contrast material in common bile duct is retained from prethermocoagulation injection.



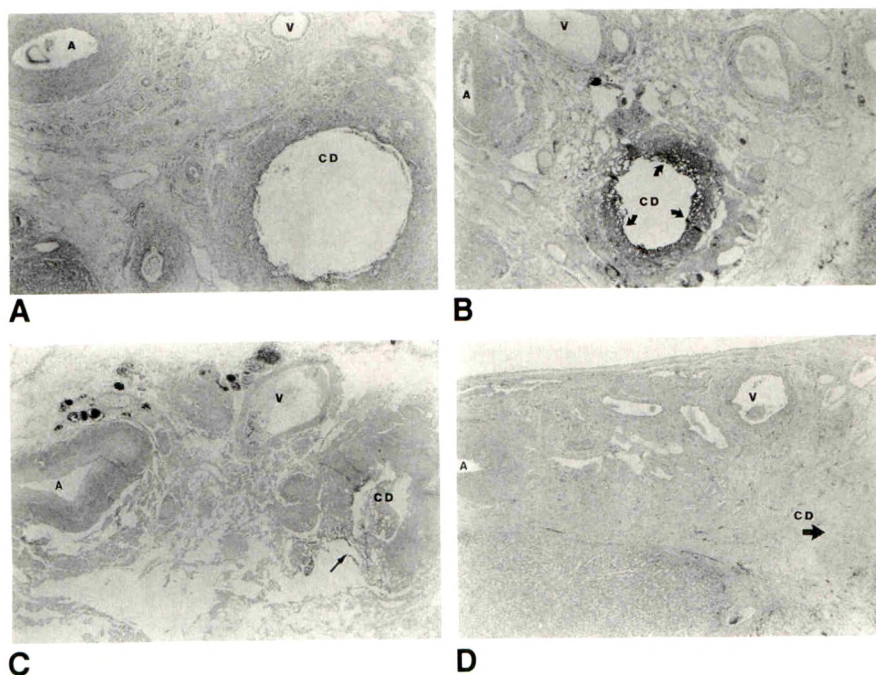


Fig. 2.—Histology of normal cystic duct and cystic duct after laser thermocoagulation (original magnification $\times 5$).

A, Photomicrograph shows normal cystic duct, artery, and vein in control animal.

B, Photomicrograph of animal sacrificed immediately after laser thermocoagulation shows circumferential injury (arrows) to cystic duct and sparing of surrounding vessels. Note that cystic duct remains patent although cholangiogram showed immediate occlusion. This may represent a fixation artifact (see text).

C, Photomicrograph of animal sacrificed 72 hr after laser thermocoagulation shows extensive necrosis of cystic duct and periductal tissues (arrow). Lumen of cystic duct contains debris.

D, Photomicrograph of animal sacrificed 6 weeks after laser thermocoagulation shows cystic duct is completely fibrosed (arrow) and cystic duct blood vessels remain intact.

A = cystic artery, V = cystic vein, CD = cystic duct.

no occlusion of the blood vessels was detected. In addition, no resected specimens (excluding the 10 pigs who underwent gallbladder sclerotherapy immediately after laser thermocoagulation of the cystic duct) showed evidence of acute cholecystitis or pericholecystic inflammation. The common bile duct was normal in all cases, including those animals who underwent gallbladder sclerotherapy.

Discussion

Chemical gallbladder sclerosis has been attempted as a way to defunctionalize the gallbladder in patients who have had nonsurgical removal of gallstones and who are unable to undergo surgical/laparoscopic cholecystectomy. Most studies to date indicate the need for permanent occlusion of the cystic duct before gallbladder sclerosis [17–22, 26]. The advantages of such a procedure include isolation of the gallbladder from the biliary-enteric circulation to prevent recurrent gallstone formation, obliteration of a potential source of epithelial cells that could reepithelialize a sclerosed gallbladder lumen, and protection of the common bile duct from chemical sclerosants.

The biological effect that laser light will have on tissues is a function of many factors, including the wavelength of the incident beam, the absorption characteristics of the target, and the duration of exposure. As laser energy is absorbed, tissue temperature rises. Initial changes occur at 43–45°C, resulting in tissue shrinkage and retraction. Further tissue heating reduces cellular enzyme activity and at approximately 60°C results in protein denaturation and coagulation. Collagen denatures at 80°C, while at 100°C, water vaporization and tissue ablation occur [23, 24].

We chose a holmium:YAG laser for cystic duct thermocoagulation because its wavelength of 2.1 μm is primarily absorbed by intracellular water. At a pulse energy of 0.1–0.5 J, this intracellular water absorption leads to protein denaturation and thermocoagulation. In addition, because of the high water content of biological tissues, most of the laser energy can be confined to the superficial tissue layers, limiting the depth of penetration to 0.5 mm [24]. Finally, the holmium:YAG laser energy can be delivered via a flexible optical fiber with a diameter of 0.6 mm.

Our study confirms the findings of Becker et al. [19], who reported that the cystic duct can be permanently obliterated by using endoluminal electromagnetic energy. Both the RF electrocoagulation used by Becker et al. and the laser thermocoagulation used in our study result in tissue heating sufficient to cause protein denaturation and coagulation. Cystic duct laser thermocoagulation is safe, as evidenced by the lack of permanent injury to the cystic artery and/or vein and the absence of acute cholecystitis. The small caliber of the laser fiber allows passage through small catheters, which has considerable technical advantages. In addition, the laser system occludes the entire cystic duct, which guarantees isolation of the gallbladder from the biliary-enteric circulation and thereby prevents recurrent gallstone formation. Furthermore, perforations of the cystic duct as a result of laser treatment remain isolated within the course of the obliterated duct.

Despite the appearance at cholangiography of occlusion of the cystic duct immediately after laser thermocoagulation, histologic specimens showed narrowed but patent lumens. Several explanations for this disparity may be given. Laser thermocoagulation causes sufficient tissue heating to result in tissue shrinkage and retraction, thereby narrowing the cystic duct lumen. In addition, the laser energy creates a

thermal trauma to the cystic duct wall, inciting an edematous reaction with further narrowing of the lumen. These two factors could result in occlusion at cholangiography, whereas histologic examination would show a persistent lumen.

In conclusion, our study demonstrates that laser obliteration of the cystic duct with a holmium:YAG laser can be performed easily and safely with no evidence of acute cholecystitis or permanent blood vessel injury, results effectively in immediate occlusion of the entire cystic duct, and leads reliably to permanent fibrous obliteration of the cystic duct at 6 weeks. The immediate occlusion of the cystic duct noted at fluoroscopy may provide the opportunity for immediate chemical gallbladder sclerosis without risk of injury to the common bile duct.

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The reader's attention is directed to the companion to this article, which appears on pages 997-999.

Cathode Rays and Controversy

One hundred years ago, Heinrich Rudolf Hertz demonstrated that cathode rays could pass through a thin metal foil of gold, silver, or aluminum. His pupil, Philipp Lenard, exploited his teacher's discoveries by constructing a vacuum tube with a thin (0.00265 cm) aluminum window sealed in the glass wall of the bulb at a point where the cathode rays were focused. By using a few particles of fluorescent potassium phosphate, on October 12, 1892, Lenard observed that the cathode rays not only penetrated through the window but also traveled several inches in free air [1]. Although the cathode rays were invisible, their effects could be studied with fluorescent substances and they could darken a photographic plate securely protected by a lightproof holder.

Lenard did not realize that the cathode rays, after passing through the aluminum window, were mixed with an abundance of another kind of ray. At the time, he was unaware that he was making "X-ray pictures."

Years later, however, Lenard became embroiled in a bitter controversy as to whether he, rather than Roentgen, should be honored as the discoverer of X-rays. Lenard initially respected and admired Roentgen and sent him a letter of congratulations on "your great discovery" [2]. In turn, Roentgen acknowledged the work of Lenard and Hertz in his famed Würzburg lecture. Roentgen and Lenard even shared two prestigious physics prizes, in Vienna in 1896 and in Paris a year later.

Lenard's unquenchable animosity began when Roentgen alone was awarded the first Nobel prize in physics in 1901. Feeling himself betrayed, Lenard proclaimed himself the true discoverer of the X-ray. Almost 70 years later, it was revealed that the Advisory Committee of the Swedish Academy of Sciences recommended that the prize be divided equally between Roentgen and Lenard. However, the full Academy disregarded this recommendation, since the late Nobel had specified that it be given only to the *single* most distinguished scientist of the year. The decision was unanimous in favor of Roentgen [3].

Even after being awarded his own Nobel prize in 1905, Lenard's animosity continued unabated. Among his statements downgrading Roentgen's efforts while glorifying his own is the following [2]:

I am the mother of the x-rays. Just as a midwife is not responsible for the mechanism of birth, so is Roentgen not responsible for the discovery of x-rays, which merely fell into his lap. All Roentgen had to do was push a button, since all the groundwork had been prepared by me.

In effect, Lenard claimed that anybody could have discovered X-rays after *his* (Lenard's) work on cathode rays. However, Lenard never gave a satisfactory explanation as to why he himself had not accomplished this task. In addition, he never mentioned that the so-called Lenard tube was actually based on Hertz's work.

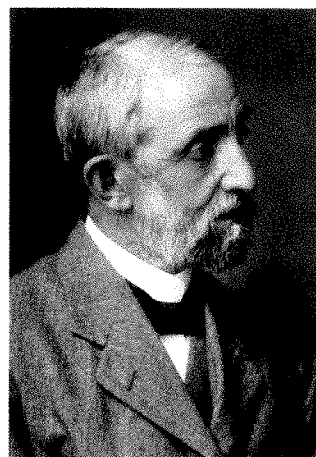
Roentgen's reaction was philosophical. As he wrote to his friend Zehnder, "Well, dear heaven, the envious are never lacking when something occurs as with me. That is always the case" [4].

Lenard's unbridled hatred of Roentgen climaxed during the time of his (Lenard's) commanding position in the Nazi hierarchy of scientists. In his four-volume work on German physics, there is no mention of Roentgen (or Einstein) in the text, but the foreword is a lengthy diatribe against the Jews. The implication, drawn by many persons in Germany, was that Roentgen was a Jew. When asked about this by American radiologist Lewis Etter, Lenard replied "No, but he was a friend of Jews and acted like one" [2].

The final chapter in the controversy occurred at the time of the 50th anniversary of Roentgen's discovery. The Physical Medical Society of Würzburg applied to the Nazi Minister of Post and Telegraph for a memorial stamp to be made in honor of Roentgen, similar to those issued for other famous scientists. The minister (Ohensorg), a physicist and student of Lenard, rejected the request, saying that the proposal was not in order since such an honor was reserved "only for the illustrious" [2]. The first German stamp honoring Roentgen was not issued until 1952.

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Philipp Lenard (1862-1947).

In preparation for the 1995 centennial celebration of the discovery of the X-ray, the *AJR* will periodically publish History Pages, which deal with events leading up to and occurring around the time of the discovery.

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Percutaneous Chemical Gallbladder Sclerosis After Laser-Induced Cystic Duct Obliteration: Results in an Experimental Model

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OBJECTIVE. Chemical gallbladder sclerosis has been attempted as a way to defunctionalize the gallbladder in patients who have undergone nonsurgical removal of gallstones and who are unable to undergo surgical/laparoscopic cholecystectomy. The purpose of this investigation was threefold: to study an animal model for chemical sclerosis of the gallbladder with 95% ethanol and 3% sodium tetradecyl sulfate, to attempt chemical sclerosis immediately after percutaneous cystic duct obliteration by laser thermocoagulation, and to assess histopathologic changes in the gallbladder after sclerosis.

MATERIALS AND METHODS. Percutaneous cholecystostomy and laser thermocoagulation of the cystic duct was performed in 13 pigs. Eight pigs underwent immediate gallbladder sclerosis with 95% ethanol and 3% sodium tetradecyl sulfate while two pigs received 95% ethanol only. The remaining three pigs served as controls. The cholecystostomy catheter was removed immediately after the procedure. All animals were sacrificed 6 weeks after laser thermocoagulation. Multiple sections through the gallbladder, which included the adjacent liver, the cystic duct, and the common bile duct, were obtained for histologic examination.

RESULTS. At autopsy, the gallbladder in all 10 animals who underwent gallbladder sclerosis was reduced in size compared with controls. In all treated animals, the gallbladder mucosa was denuded; however, in nine of 10 cases reepithelialization had occurred. Complete sclerosis without reepithelialization was achieved in one pig who received both ethanol and sodium tetradecyl sulfate. In the two animals who received ethanol only, the depth of wall necrosis around the gallbladder lumen was less than in those pigs who received both ethanol and sodium tetradecyl sulfate. No pigs showed signs of hepatic necrosis or injury to the common bile duct.

CONCLUSION. Cystic duct laser thermocoagulation allows immediate gallbladder sclerotherapy without injury to the common bile duct. Sclerosis with ethanol and sodium tetradecyl sulfate results in denudation of the gallbladder mucosa. However, a single therapeutic session with immediate removal of the cholecystostomy catheter was inadequate for gallbladder ablation in this model because of reepithelialization.

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The use of nonsurgical approaches to gallstone disease in patients for whom the risks of operation are high has spurred interest in alternatives to surgical/laparoscopic cholecystectomy [1-16]. Isolating the gallbladder from the biliary-enteric circulation by means of percutaneous cystic duct occlusion abolishes the risk of recurrent gallstone formation. The isolated gallbladder, however, remains intact and may theoretically undergo malignant degeneration or develop into a mucocele with an inherent risk of infection [17-26]. Becker et al. [17-19, 27] have shown that 95% ethanol and 3% sodium tetradecyl sulfate (STS) can be used to perform percutaneous chemical cholecystectomy.

The purpose of this study was threefold: to confirm the feasibility in an animal model of chemically sclerosing the gallbladder with 95% ethanol and 3% STS, to attempt chemical sclerosis immediately after percutaneous cystic duct obliteration

by laser thermocoagulation, and to assess histopathologic changes in the gallbladder after sclerosis.

Materials and Methods

Under mask general anesthesia (halothane) and in compliance with National Institutes of Health guidelines for the care of laboratory animals, 13 female domestic pigs weighing approximately 25 kg each underwent percutaneous transhepatic cholecystostomy (5-French catheter) and holmium:yttrium-aluminum-garnet (YAG) laser thermocoagulation of the cystic duct. The technical details of the procedure are described in our companion article [28]. After cystic duct thermocoagulation, a contrast-enhanced (Urovis 14%, Berlex Laboratories, Wayne, NJ) cholecystogram under fluoroscopic guidance was obtained to assess occlusion of the cystic duct. To ensure adequate assessment of cystic duct occlusion, we instilled a volume of contrast material equal to twice the prethermocoagulation contrast volume needed to opacify the cystic duct. Gallbladder sclerosis was achieved in 10 animals immediately after cystic duct obliteration by aspirating the gallbladder dry and instilling 95% ethanol for 20 min with agitation (repeated aspiration and reinjection). Agitation was used to ensure that the entire mucosa came into contact with the sclerosants. The volume of ethanol instilled was equal to the volume of contrast material injected for the cholecystogram after cystic duct thermocoagulation. After the ethanol was completely removed, an equal volume of 3% STS was instilled for 20 min with agitation in eight animals. In the other two pigs, the catheter was inadvertently withdrawn from the gallbladder after ethanol therapy, and STS was not administered. After aspiration of the STS, the 5-French catheter was removed from the gallbladder and the skin puncture site bandaged. Controls ($n = 3$) consisted of animals who had cystic duct laser thermocoagulation but no gallbladder sclerosis.

All 13 animals were sacrificed 6 weeks after laser thermocoagulation. The liver, gallbladder, cystic duct, common bile duct, and duodenum were resected en bloc and fixed in formalin. Multiple cut sections through the gallbladder, which included the adjacent liver, the cystic duct, and the common bile duct, were obtained and stained with hematoxylin and eosin for microscopic examination by an experienced pathologist.

Results

The cholecystographic contrast volume needed to opacify the cystic duct before thermocoagulation was 9.0 ± 5.6 ml. The average volume of contrast material injected into the gallbladders after cystic duct thermocoagulation was 17.4 ± 2.8 ml. The amount of ethanol and STS instilled into the gallbladders for sclerotherapy was equal to the volume of contrast material injected after laser thermocoagulation of the cystic duct.

The aspirate from the gallbladder after ethanol administration typically contained hemorrhagic debris, while the STS aspirate was usually clear and yellow without debris. The amount of sclerosant aspirated was approximately equal to the amount infused, consistent with observed occlusion of the cystic duct.

At autopsy, the gallbladder in all 10 animals who underwent gallbladder sclerosis was reduced in size compared with the controls, and the lumens were filled with hemorrhagic necrotic debris that was firm on palpation (Fig. 1). In all cases, the gallbladder mucosa had been diffusely denuded; however, in nine of 10 animals reepithelialization occurred (Figs. 2A and 2B). Complete diffuse and uniform sclerosis without reepithe-

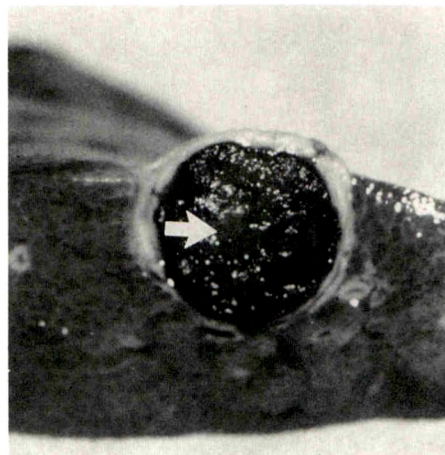


Fig. 1.—Photograph of autopsy specimen 6 weeks after gallbladder ablation shows small sclerosed gallbladder with lumen containing hemorrhagic necrotic debris (arrow).

lialization was achieved in one animal who received both ethanol and STS (Fig. 2C).

In the two pigs who received ethanol only, the depth of necrosis was asymmetric around the gallbladder lumen and consistently less than in those pigs who received both ethanol and STS. All animals had areas of mild fibrosis in the tissues adjacent to the gallbladder; however, no pigs showed signs of hepatic necrosis or injury of the common bile duct. The three control animals had normal gallbladders, cystic duct fibrosis, and normal common bile ducts. The gallbladders in the control group were distended and filled with clear to yellow fluid containing minimal debris.

Discussion

Our study confirms the findings of Becker et al. [17–19, 27] that 95% ethanol and 3% STS are effective gallbladder sclerosants. In all 10 pigs, the gallbladder mucosa was denuded by the sclerosants. In nine of 10 animals, however, reepithelialization with a characteristic epithelial monolayer occurred (Fig. 2B). The source of reepithelialization is unclear but was unlikely to be the cystic duct, given that the animals sacrificed immediately after laser thermocoagulation showed complete circumferential destruction of the cystic duct mucosa, which by 6 weeks later was totally fibrosed [27]. More likely, islands of gallbladder mucosa were not destroyed by the chemical sclerosants. The aspirate from the ethanol injection was typically filled with debris, presumably from sloughed mucosa that settled to the bottom of the collection syringe. It is possible that sloughed material settled to the dependent portions of the gallbladder and protected the mucosa of this portion of the gallbladder from the chemical sclerosants. This protected mucosa could then become a source of epithelial cells to allow reepithelialization of the gallbladder once the sclerosants were removed.

It is clear that a single course of chemical sclerosis such as we used is inadequate for gallbladder ablation. A catheter should probably remain within the gallbladder after therapy to allow both repeated courses of sclerotherapy (if necessary)

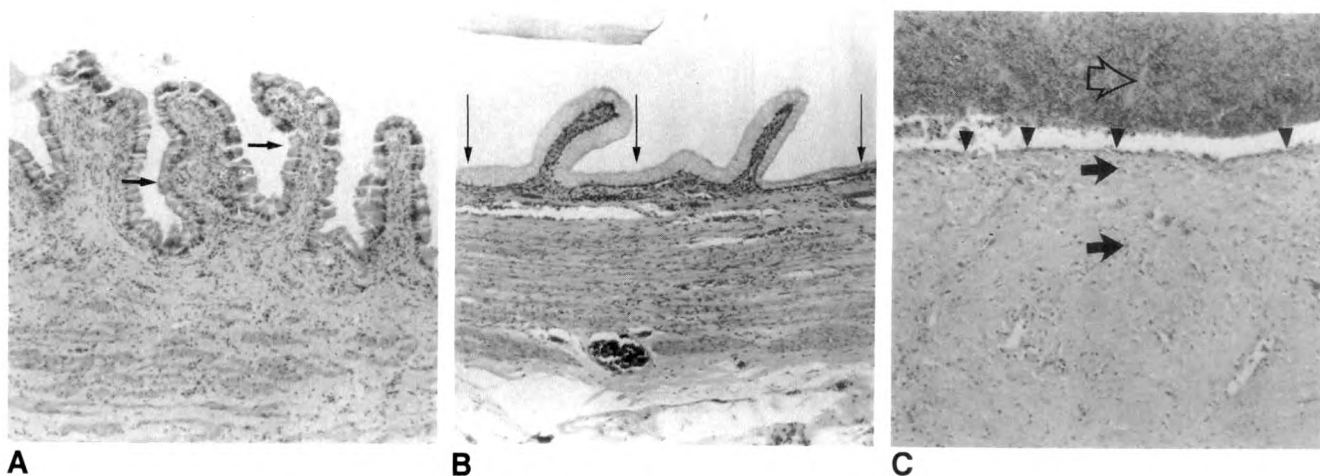


Fig. 2.—Photomicrographs show pathologic changes in gallbladders of control and treated animals 6 weeks after a single course of chemical sclerosis (magnification $\times 10$).

A, Normal gallbladder mucosa (arrows) is papillary and composed of columnar epithelial cells.

B, Denuded gallbladder mucosa has reepithelialized with a characteristic epithelial monolayer (arrows).

C, Completely sclerosed gallbladder mucosa (arrowheads). Gallbladder lumen is filled with necrotic debris (open arrow). Gallbladder wall is completely replaced by fibrosis (solid arrows).

and drainage of the necrotic debris so that the gallbladder can collapse around the catheter, promoting fibrosis. The results of this study suggest, however, that gallbladder sclerosis can begin immediately after laser obliteration of the cystic duct without risk of damaging the common bile duct rather than being performed as a delayed procedure, as previously suggested [17–19]. The potential benefits of sclerosing the gallbladder immediately include increased tolerance by patients and shorter time to complete gallbladder obliteration.

In summary, the rapid occlusion of the cystic duct with a holmium:YAG laser allows immediate gallbladder sclerotherapy without the risk of injuring the common bile duct. Both 95% ethanol and 3% STS were effective sclerosants in this model in that they resulted in denudation of the gallbladder mucosa. However, a single therapeutic session with immediate removal of the cholecystostomy catheter did not prevent reepithelialization of the gallbladder wall.

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Book Review

Nuclear Medicine Procedure Manual, 2nd ed. Edited by Wm. C. Klingensmith III, Dennis Eshima, and John Goddard. Englewood, CO: Wick Publishing, 123 pp., 1992. Print format, \$155; disk format, \$135; both formats, \$245

The Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) is scheduled to visit your facility and your manual for nuclear medicine procedures has not been revised, much less reviewed, since their last visit. The solution is simple if you have a copy of the *Nuclear Medicine Procedure Manual* available on floppy disk.

The *Nuclear Medicine Procedure Manual* by Klingensmith et al. is a 123-page document in a three-ring notebook and is more than adequate to meet the requirements of most nuclear imaging departments. The entire document also is available in digital format on 3½- and 5¼-in. floppy disks for either IBM or Apple Macintosh personal computers. Individual sections (e.g., procedures) are stored as separate files in five subdirectories, which follow the general organization of the manual. Topics include general policies on performing studies, departmental guidelines, quality control/assurance of instrumentation, laboratory and radiochemistry procedures, regulatory agencies, and diagnostic procedures.

The disks and the manual can be purchased separately. The entire contents of the manual can be printed from the disks, but expect to produce more than 200 single-sided pages. You may not want or need to print all the sections. The disks are available in several popular word processing software formats such as WordPerfect and Microsoft Word for IBM and MacWrite II and Microsoft Word for Apple Macintosh. ASCII-formatted files are also available, which can be imported into almost any other word processing software program for editing and printing.

The authors have included virtually all the routine diagnostic procedures performed in nuclear medicine. The details of each test are

presented in a standard format and include the indications for the procedure, the administered dose, preparation of the patient, the time between administration of the dose and imaging, camera position, desired number of counts per image, and more. The outlines have sufficient details to serve as a guide for technologists and other personnel. Most procedures are summarized in no more than three pages, including radiation dosimetry data and a remarkably current reference list of clinically pertinent articles.

Although users may wish to modify the details of some of the procedures to suit their laboratory's requirements, most radiologists will find little need to edit the text except to perhaps include the name of their institution and indicate the date of the last review. These details can be added in the footer information at the bottom of each page by anyone familiar with word processing. The results will be an accurate, up-to-date nuclear medicine procedure manual that will be impressive as well as useful.

Included in the initial section of the manual is what may be one of the best and most complete descriptions of such topics as instrument quality control, doses of radiation as low as reasonably achievable (ALARA), and federal regulatory information. Users may still want to add sections that describe their department's organization, responsibilities of personnel, physician privileges, and so forth, to meet JCAHO requirements.

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Gastric and Duodenal Obstruction in Patients with Cholangiocarcinoma in the Porta Hepatis: Increased Prevalence After Radiation Therapy

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Bronwyn Jones¹
John L. Cameron²
JoAnn Coleman²

OBJECTIVE. Our objective was to study the imaging findings in patients who had gastric and duodenal obstruction as a long-term complication of cholangiocarcinoma and to determine if the obstruction was associated with radiation therapy.

MATERIALS AND METHODS. Between 1973 and 1989, 96 patients had either curative resection or palliative stenting for cholangiocarcinoma involving the hepatic duct bifurcation. Sixty-three (66%) also received adjuvant radiation therapy ranging from 4960 to 7220 rad (cGy). Gastric outlet or duodenal obstruction or both developed subsequently in seven of the 63 patients treated with radiation therapy. Radiographic studies, including upper gastrointestinal series and CT, and medical and surgical records for these seven patients were retrospectively reviewed.

RESULTS. Upper gastrointestinal series in the seven patients with obstruction showed narrowing of the lumen, deformity and enlargement of gastric and duodenal mucosal folds, and delayed gastric emptying. CT performed in five of the seven patients showed thickening of the wall of the gastric antrum and small bowel and retained food and fluid within the stomach. All seven patients required gastrojejunostomy; at surgery, dense adhesions and fibrosis were found, and it was not evident whether the obstruction was due to the tumor or to radiation fibrosis. However, because this complication was seen only after radiotherapy, it was presumed to be radiation fibrosis.

CONCLUSION. Our experience suggests that radiation therapy increases the risk of postoperative gastric and duodenal obstruction in patients undergoing surgery for cholangiocarcinoma.

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Cholangiocarcinoma, or adenocarcinoma of the biliary ducts, may arise from any location within the biliary tree and spread through either local invasion or by metastases to abdominal lymph nodes and the pulmonary and osseous systems [1]. Although initially described by Altemeier et al. [2] in 1957, a more recent large study continued to show less than 50% survival beyond 6 months [1]. The longest survival rates have been reported for those patients undergoing surgical resection [3]. The additional benefit of radiotherapy to the treatment regimen remains controversial [4-6].

Obstruction of the stomach or duodenum or both appears as a possible long-term complication of cholangiocarcinoma and may in fact be related to radiation therapy. We present our findings in patients with cholangiocarcinoma in whom obstruction subsequently developed, and stress that gastric outlet and/or duodenal obstruction occurred only in patients who underwent irradiation and other treatment.

Materials and Methods

Between 1973 and 1989, 96 patients with cholangiocarcinoma were operated on at The Johns Hopkins Hospital. Of these, 53 had surgical resection, and the remaining 43 were

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treated with palliative stenting because of either disseminated tumor or tumor involving both hepatic lobes, the main portal vein, or the hepatic artery. Sixty-three patients (66%) underwent postoperative radiation therapy, consisting of external beam irradiation, in amounts usually between 5000 and 6000 rad (cGy). Additionally, 31 patients subsequently were treated with 2000 rad (cGy) delivered by internal iridium-192 seeds placed in transhepatic biliary stents. Of the 63 patients treated with radiotherapy, 38 were from the group receiving surgical resection and 25 had received palliative stenting.

Seven patients subsequently had signs or symptoms of either gastric outlet or duodenal obstruction. Each patient was examined radiographically with an upper gastrointestinal series. In five of the seven, abdominal CT scans also had been obtained either at that time or recently and were available for comparison. These studies were retrospectively reviewed, and medical and surgical records were analyzed in comparison with findings in the remainder of the treatment group.

Results

If the four patients who died in the hospital and the four patients who had initial gastrojejunostomy are not included, 88 patients remained, of whom 62 were irradiated and 26 were not. The seven patients in whom symptomatic obstruction developed subsequently had all received radiation therapy; four had their primary tumor surgically resected and three had palliative stenting. None of the 26 patients who did not receive radiation therapy had this complication. The average radiation dose received by these seven patients was 5850 rad (cGy), with a minimum of 4960 rad (cGy) and a maximum of 7220 rad (cGy). Two of the seven patients had intracavitary iridium-192 implants, accounting for 2000 rad (cGy) of their total radiation therapy. The duration of radiation therapy varied, from as short as 46 days to as long as 13 months. The period from the end of radiotherapy to the date of gastrojejunostomy for relief of obstruction varied from a minimum of 5 months to a maximum of 4 years 5 months.

The barium upper gastrointestinal series in each of the seven cases showed moderate to marked deformity and luminal narrowing in the proximal portion of the duodenum. The mucosal folds were thickened, distorted, and, in some patients, obliterated (Fig. 1). In three of the seven patients, gastric emptying was delayed or food and fluid were retained in the stomach. In four patients, antral and pyloric deformity with enlarged folds and luminal narrowing were seen. One study additionally showed a small antral ulcer with a probable second larger, eccentrically located ulcer (Fig. 2A).

CT showed retained gastric contents in three of five patients, three patients with thickening of the gastric wall and two patients with wall thickening of the C loop (Fig. 2B). In one patient, the thickening of the second portion of the duodenum was described as masslike, extending to the head of the pancreas and compatible with either inflammation, recurrent tumor, or radiation fibrosis.

All seven patients subsequently underwent gastrojejunostomy for relief of obstruction. At surgery, dense adhesions and fibrosis were seen in all patients, sometimes in combination with residual tumor. Pathologic specimens were available for only three patients. Two of the specimens showed cholangiocarcinoma, one of which showed infiltrating adenocarcinoma in dense fibrous tissue.

Discussion

With the advent of earlier diagnosis through a combination of CT, sonography, and cholangiography, in conjunction with either curative or palliative surgical intervention, the prognosis for patients with cholangiocarcinoma has become more optimistic. The overall survival rates 1, 3, 5, and 10 years after surgery for the 96 patients treated at our institution were 49%, 12%, 5%, and 2%, respectively. Not surprisingly, those treated with resection had an even better prognosis, with 1-,

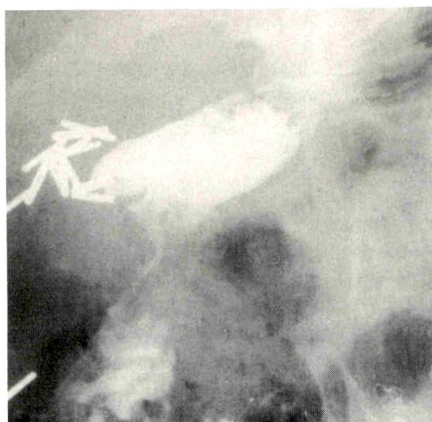
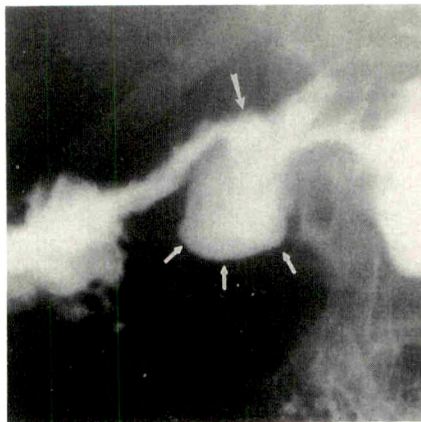
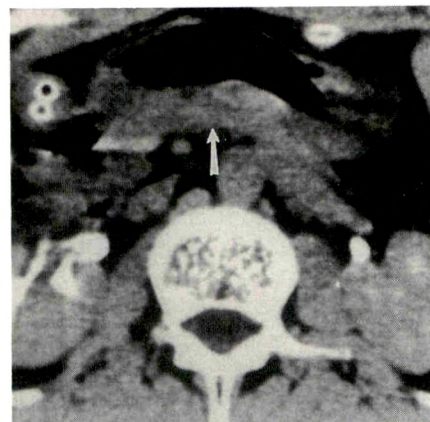


Fig. 1.—64-year-old man with cholangiocarcinoma treated with palliative stenting. Spot film from an upper gastrointestinal series shows marked narrowing of second portion of duodenum with obliteration of normal pattern of mucosal folds.



A



B

Fig. 2.—38-year-old man with cholangiocarcinoma treated with surgical resection. A, Upper gastrointestinal series reveals marked deformity of duodenal bulb with one small ulcer (large arrow) and probably a larger, eccentrically located ulcer (small arrows). Additionally noted is a 4-cm region of postbulbar narrowing compatible with spasm or fibrosis. B, CT scan shows moderate thickening of antral wall (arrow). Biliary stents also are noted.

3-, 5-, and 10-year survival rates of 66%, 21%, 8%, and 4%, respectively [3].

The role of radiotherapy in the treatment of cholangiocarcinoma remains controversial. External beam radiation, often used in conjunction with internal iridium-192 implants, has long been advocated for palliation of biliary carcinoma [7-9]. Doses varying between 2500 and 6000 rad (cGy) have been used, with nausea, vomiting, and gastric ulceration the complications most often reported [10]. Unfortunately, because of the generally poor survival rate, little has been documented on possible long-term benefits or complications of radiation therapy for cholangiocarcinoma.

In patients treated by palliative stenting at our institution, those who received radiation therapy had a statistically significant increase in the survival rate when compared with those who did not receive radiotherapy. However, in the patients treated by resection, no statistically significant increase in survival rate was seen with the addition of radiation therapy [3].

The effects of radiation on the bowel have been well described [11-13]. The minimum dose related to gastrointestinal injury is approximately 4200-4500 rad (cGy). Patients usually become symptomatic within 6-24 months after treatment [12]. On barium examination, findings consist of ulceration, effacement of mucosal folds, and smooth strictures. The additional CT findings of radiation injury include thickening of bowel loops in a matted serpentine pattern and thickening and increased density of the mesentery [13].

In our series, gastric outlet and/or duodenal obstruction developed in seven of 96 patients with cholangiocarcinoma. All had been treated with radiation therapy. Obstruction did not develop in any patients who did not receive radiation therapy. In all seven cases, the findings on barium studies and CT were compatible with obstruction due to either gastrointestinal radiation injury or recurrent tumor. If obstruction were purely related to recurrent or residual tumor, however, the rate should be greater among those patients treated with palliative stenting, because these patients had more advanced disease at the time of initial surgery. Also, if obstruction were

occurring only because of prolonged survival, then patients not treated with radiotherapy also should have developed obstruction.

The results in patients with cholangiocarcinoma treated surgically at our institution suggest that an increased risk of gastric outlet and/or duodenal obstruction may be associated with adjuvant radiation therapy. Although the radiographic appearances of radiation bowel injury and recurrent tumor are similar, the early detection of these changes could prevent considerable morbidity.

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Book Review

Gamuts in Ultrasound. By Michael R. Williamson and Susan L. Williamson. Philadelphia: Saunders, 240 pp., 1992. \$25

In style and organization, this book is the sonographic offspring of Reeder and Felson's well-known *Gamuts in Radiology*. The book is divided into three main parts: adult, obstetrics, and pediatric. Each part is in turn divided into general categories such as organs, organ systems, or body regions, and within each of these categories lists of differential diagnoses are given for a variety of sonographic findings. Thus, for example, a list of a dozen causes of hypotelorism can be found in the "Obstetrics: Fetal Head and Face" section. As is the case with *Gamuts in Radiology*, many of the lists are subdivided into common and uncommon causes, and relevant references are given after most of the lists. Considerably more references are provided in this book than in *Gamuts in Radiology*; nevertheless, references are by no means provided for every item in the differential lists. Unlike the parent text, a "Comments" column is included to provide brief additional information on some of the entities. For example, the comment "may present as target lesion; hypoechoic lesion" follows *Candida* or fungus as an uncommon cause of a focal splenic abnormality. These comments are intended to help distinguish other entities with similar findings and to reduce the number of differential diagnoses considered.

The book is quite satisfactory in its coverage of a wide range of sonographic findings. Before opening it, I decided to list 50 sonographic findings that I thought should be among those included in a text with this title. Although I found a few variations in specific categories, most of the information I sought is readily available. For example, I might have included a specific section on thickening of the bowel wall in the right lower quadrant, but most of the entities that would be included in this more specific category are included in a general list of causes of thickening of the bowel wall. The individual lists are quite exhaustive, although as with any book of this nature,

some omissions occur; for example, extrapulmonary *Pneumocystis* as a cause of focal splenic, hepatic, or renal lesions or increasing age as a differential consideration for an echogenic pancreas. Similarly, some of the categorizations are debatable. I would argue, for instance, that obstruction of the bladder outlet, particularly that caused by benign prostatic hyperplasia, should be listed as a common cause of thickening of the bladder wall rather than an uncommon cause, as in this book. Overall, however, it takes some searching to come up with such details.

For the sake of completeness, I must point out that no sonograms or diagrams are included in this text. This is not meant to be a criticism, as it is clear that the addition of such features would take away the book's advantages of low cost and conciseness. Also, no standards are given for the recognition of sonographic findings; the user of this text must know what constitutes increased diameter of liver vessels or decreased pancreatic echogenicity. My own feeling is that brief criteria (particularly with reference to organ or structure sizes) might be helpful, but again this would expand the size and expense of the book.

I expect sonographers will find this book a useful reference; I, for one, have too much trouble recalling what Zellweger syndrome is to remember to include it as being associated with renal cysts in children. The book is a bargain at its low price and is certainly of sufficient quality to take its place next to similarly patterned texts.

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The Distinction Between Benign and Malignant Liver Tumors on Sonography: Value of a Hypoechoic Halo

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OBJECTIVE. The purpose of this study was to determine the diagnostic value of the sonographic halo sign (defined as any hypoechoic rim in the periphery of a lesion) in distinguishing between benign and malignant isoechoic and hyperechoic liver lesions on sonography.

MATERIALS AND METHODS. Sonograms of the liver in 50 patients with proved benign liver tumors and in 50 patients with proved malignant liver tumors (seven primary liver neoplasms, 43 metastases) selected during a 13-month period were retrospectively analyzed by four radiologists who had no knowledge of the patients' clinical findings or the final diagnoses. Only a single sonogram was studied in each case. The presence or absence of a hypoechoic halo on the sonogram was the only criterion for distinguishing malignant from benign hepatic lesions.

RESULTS. For 95 of 100 hepatic lesions, the four radiologists were almost (three vs one) or completely (four vs zero) in agreement about the presence or absence of a hypoechoic halo. In the five cases where there were conflicting decisions (two vs two), a final decision (four vs zero) was achieved by reviewing the entire series of sonographic images. A halo could be detected in 44 malignant tumors (88%) and in only seven benign tumors (14%) (sensitivity, 88%; specificity, 86%; positive and negative predictive values, 86% and 88%, respectively). The sonographic halo sign was particularly helpful in distinguishing hemangiomas ($n = 29$) from metastases ($n = 43$) (positive and negative predictive values, 95% and 87%, respectively).

CONCLUSION. The results of this study suggest that the halo sign on sonograms is useful to distinguish benign from malignant isoechoic or hyperechoic tumors.

AJR 159:1005-1009, November 1992

Despite the increasing availability of CT and MR imaging units, sonography continues to play an important role as a primary screening and surveillance technique in hepatic imaging. Liver tumors have a broad spectrum of sonographic features, which, in experienced hands, may help reduce the number of entities considered in the differential diagnosis [1, 2]. However, hyperechoic and isoechoic liver lesions are difficult to classify because both metastases and hemangiomas, the most common malignant and benign liver lesions, respectively, may show these two types of echogenicity. Unlike hemangiomas, isoechoic and hyperechoic metastases are often surrounded by a hypoechoic halo [3]. In a sonographic-histopathologic correlation study [4], we observed that this hypoechoic halo corresponded primarily to an intratumoral rim of proliferating tumor cells. However, the value of this sonographic feature in distinguishing benign from malignant lesions is as yet uncertain, as its exact frequency in malignant liver tumors is unknown. In addition, benign lesions sometimes have a hypoechoic halo [1, 2, 5, 6].

In order to determine the diagnostic value of the sonographic halo sign in differentiating benign from malignant isoechoic or hyperechoic liver lesions, the sonograms of 50 proved malignant and 50 proved benign lesions were retrospectively analyzed by four radiologists.

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Materials and Methods

Selection of Hepatic Lesions

We reviewed reports and sonograms of the liver of patients in whom isoechoic or hyperechoic liver lesions were detected during a 13-month period (January 1989 to February 1990). The diagnosis of a malignant hepatic tumor was considered confirmed if biopsy results indicated a malignant lesion or if reports of follow-up indicated that the tumor had enlarged. The diagnosis of a benign tumor was considered proved if histologic examination of tissue obtained during surgery or percutaneous biopsy showed no evidence of a malignant lesion or if other imaging techniques (dynamic bolus CT, scintigraphy) showed specific morphologic findings or no change in the size and structure of the lesion over a period of at least 12 months.

The study material consisted of sonograms of 50 proved malignant tumors (selected during the first 5 months) and 50 proved benign hepatic lesions (selected during all 13 months of the study). The mean age of the patients was 43 years (range 20–81 years). The malignant tumors included six hepatocellular carcinomas, one peripheral cholangiocarcinoma, 17 metastases of colonic cancer, two gastric cancers, one pancreatic cancer, three carcinoids, one gastrinoma, four teratocarcinomas, one testicular cancer, one breast cancer, two renal cell carcinomas, one squamous cell carcinoma, five leiomyosarcomas, two melanomas, one anaplastic carcinoma of unknown origin, and two Hodgkin's lymphomas. These diagnoses were confirmed on the basis of biopsy results in 12 and on the basis of follow-up examinations in 38. Tumor diameter ranged from 1.0 to 15 cm (mean, 5.5 cm).

The 50 benign hepatic lesions included 29 hemangiomas, nine focal fatty infiltrations, three focal nodular hyperplasias, two adenomatous hyperplasias, one regenerating nodule, four abscesses, and two hematomas. The diagnoses were confirmed on the basis of biopsy reports in 24, characteristic findings on dynamic bolus CT and unaltered size and structure on follow-up examination in 22, characteristic findings on sulfur colloid scintigraphy in one, and findings on follow-up examinations alone in three. The diameter of all benign lesions ranged from 0.5 to 15 cm (mean, 5.0 cm).

Image Analysis

Sonograms of all the lesions were presented in a random sequence to each of four radiologists who had no knowledge of the patients' clinical history and final diagnoses. In 31 patients who had multiple metastases, an image of a single metastasis displaying a representative feature of all lesions was selected for presentation to the

radiologist. The presentation of a single lesion was preferred in order to avoid bias, because multiple lesions would favor the diagnosis of malignant disease. Six of 31 patients with multiple metastases had both hyperechoic or isoechoic and hypoechoic hepatic lesions. In these cases, only hyperechoic or isoechoic lesions were selected for presentation.

Each radiologist indicated if a hypoechoic halo was present or absent. A sonographic halo was defined as any peripheral rim of tissue (irrespective of the rim's thickness) that had a lower echogenicity than the center of the lesion and surrounding liver parenchyma. Because edge shadowing can simulate a hypoechoic rim at the lateral boundaries of a lesion, the radiologists mainly analyzed those regions where the edge of the lesion was more or less parallel to the sonic wave fronts (i.e., anterior and posterior borders).

Evaluation of the Results

The radiologists' decisions concerning the presence or absence of a hypoechoic halo were compared. All cases with conflicting decisions (two vs two) were reviewed by all radiologists together in a second session; the whole series of sonograms of each lesion in question was presented to facilitate a final decision. The observers' final decisions were subsequently compared with the final diagnoses. The presence or absence of a halo was interpreted as indicating that the lesion was malignant or benign, respectively. The halo sign was scored as true-positive when a lesion with a hypoechoic halo was a malignant tumor. The halo sign was scored as true-negative when a lesion without a hypoechoic halo was benign. The results were analyzed statistically (sensitivity, specificity, and positive and negative predictive values) to determine the value of the sonographic halo sign in distinguishing malignant from benign hepatic lesions.

Results

In 95 of 100 hepatic lesions, the four radiologists were almost (three vs one, $n = 16$) or completely (four vs zero, $n = 79$) in agreement about the presence ($n = 47$) or absence ($n = 48$) of a hypoechoic halo (Figs. 1–11). In those five cases in which they disagreed initially (two vs two), the final decision (four vs zero) was that four lesions had a hypoechoic halo and one had no halo. A hypoechoic halo was detected in 44 malignant tumors (88%) (Figs. 1–4) and in only seven benign lesions (14%) (Figs. 5 and 6). For distinguishing benign from

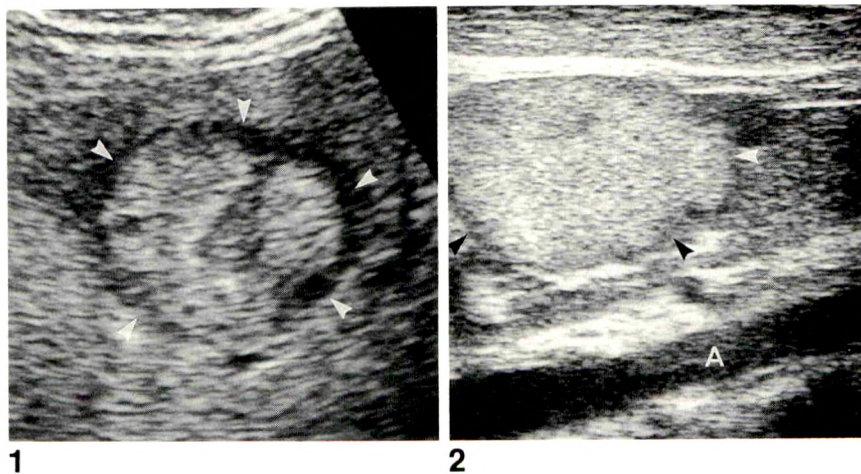


Fig. 1.—Sonogram of a 62-year-old man with peripheral cholangiocarcinoma shows a 4.0-cm tumor with a hypoechoic halo (arrowheads).

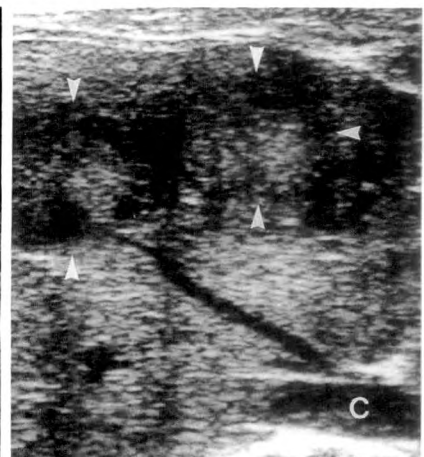
Fig. 2.—Sonogram of a 56-year-old man with carcinoid shows a homogeneous hyperechoic 6-cm metastasis surrounded by a hypoechoic halo (arrowheads). A = aorta.

Fig. 3.—Sonogram of a 67-year-old woman with adenocarcinoma of the colon shows a 4.5-cm isoechoic metastasis that can be delineated from surrounding liver tissue only by its faint hypoechoic halo (arrowheads).



Fig. 4.—Sonogram of a 30-year-old woman with melanoma shows two isoechoic metastases 3.0 and 3.5 cm in diameter with extremely broad hypoechoic rims (arrowheads) having poorly defined outer and inner borders. C = inferior vena cava.

3



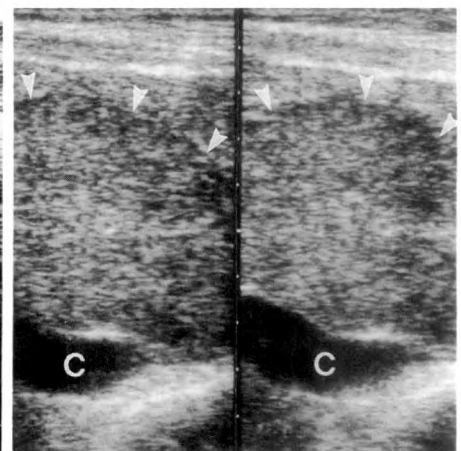
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Fig. 5.—Sonogram of a 46-year-old woman with hemangioma shows a 4.5-cm hyperechoic lesion with bulging of liver contour and unequivocal hyperechoic halo (arrowheads).



5

Fig. 6.—Sonogram of a 47-year-old woman with focal nodular hyperplasia shows a 7-cm isoechoic tumor with a faint hypoechoic halo (arrowheads). C = inferior vena cava.



6

malignant lesions, the halo sign had a sensitivity of 88%, a specificity of 86%, and positive and negative predictive values of 86% and 88%, respectively. In malignant tumors, five (71%) of seven primary liver neoplasms (Fig. 1) and 39 (91%) of 43 metastases (Figs. 2–4) showed a hypoechoic halo. The ranges of sizes of malignant lesions with and without halos were 1.5–15.0 cm (mean, 5.5 cm) and 3.0–12.0 cm (mean, 7.0 cm), respectively.

In benign tumors, only two (7%) of 29 hemangiomas (Fig. 5) and one (25%) of four abscesses had a hypoechoic halo. All nine focal fatty infiltrations (Fig. 10), all two abscesses, and one regenerating nodule had no halo. It is important to note that all three focal nodular hyperplasias (Fig. 6) and one of two adenomas had a hypoechoic halo.

Thirteen (45%) of 29 hemangiomas had an atypical appearance on sonograms (focal internal hypoechoic zones or a peripheral hypoechoic rim) (Figs. 8 and 9). Twenty-three of 29 hemangiomas were larger than 3 cm in diameter (range, 1–15 cm; mean, 4.8 cm). The ranges of sizes of hemangiomas with and without halos were 3.0–3.5 cm and 1.0–15.0 cm (mean, 4.9 cm), respectively.

For distinguishing isoechoic or hyperechoic metastases from hemangiomas, the halo sign had a sensitivity of 88%, a specificity of 93%, and positive and negative predictive values of 95% and 87%, respectively.

Discussion

Liver tumors can be classified into four groups according to their echogenicity relative to surrounding liver tissue: anechoic, hypoechoic, isoechoic, or hyperechoic. The differential diagnosis of hypoechoic liver lesions includes widespread malignant tumors (such as metastases and hepatocellular carcinomas) and rare benign tumors (focal nodular hyperplasia, hepatic adenoma, adenomatous hyperplasia, and, less often, hemangiomas in a diffusely fatty liver or inflammatory granulomas). For statistical reasons, most hypoechoic liver lesions are probably malignant (with the exception of focal sparing in fatty infiltration of the liver, which normally has rather characteristic sonographic features) [2]. Hyperechoic and isoechoic liver lesions are more difficult to classify be-

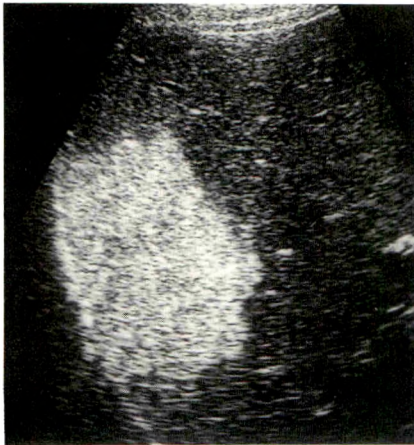


Fig. 7.—Sonogram of a 30-year-old man with hemangioma shows a completely homogeneous hyperechoic 6.5-cm lesion with irregular contours but no hypoechoic halo. This lesion has the classical morphologic features of a typical hemangioma.

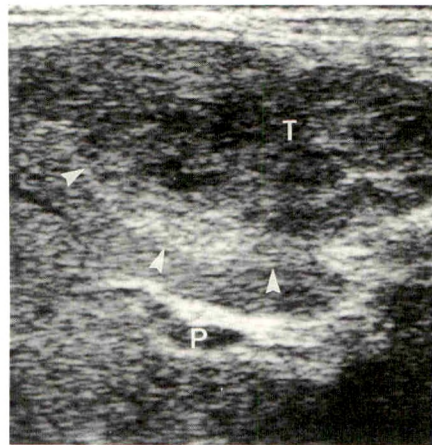


Fig. 8.—Sonogram of a 74-year-old man with hemangioma shows a 10-cm tumor (T) with both hyperechoic and hypoechoic areas and a smooth border (arrowheads). No halo is evident. P = right portal vein.

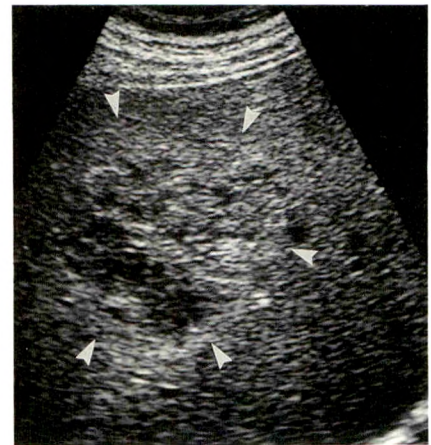
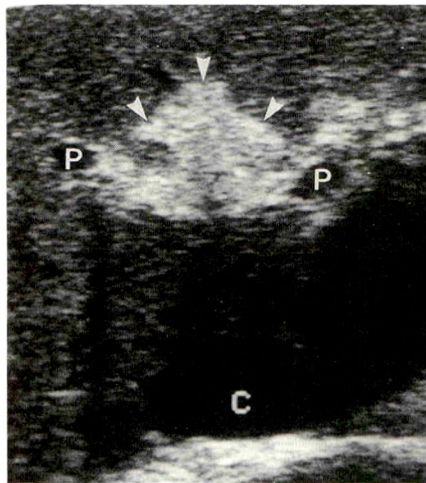
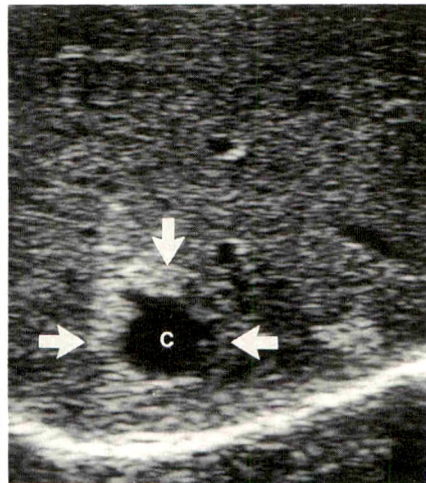


Fig. 9.—Sonogram of a 32-year-old woman with hemangioma shows a hyperechoic tumor with multiple hypoechoic areas. Note smooth border between tumor and liver parenchyma (arrowheads).



10



11

Fig. 10.—Sonogram of a 62-year-old woman with focal fatty infiltration of liver shows a 3.5-cm hyperechoic lesion with irregular margins (arrowheads) anterior to porta hepatis. P = right and left portal veins, C = inferior vena cava.

Fig. 11.—Sonogram of a 44-year-old woman with renal cell carcinoma shows a 3.0-cm hyperechoic metastasis with a central anechoic area (C). Note smooth border between tumor and surrounding liver parenchyma (arrows).

cause both metastases and hemangiomas may show these two types of echogenicity.

Our results indicate that in hyperechoic and isoechoic hepatic tumors, the halo sign is a highly objective (low interobserver variation) diagnostic criterion for distinguishing between malignant and benign lesions (positive and negative predictive values, 86% and 88%, respectively). The halo sign was especially useful in distinguishing liver metastases from hemangiomas (positive and negative predictive values, 95% and 87%, respectively).

Only seven benign tumors in our study (three focal nodular hyperplasias, one adenoma, two hemangiomas, and one abscess) had a hypoechoic halo and were incorrectly interpreted as being malignant (Figs. 5 and 6). Only two (7%) of our 29 hemangiomas had a hypoechoic halo (Fig. 5). This finding is in accordance with those of other authors [5, 6], who reported

that a peripheral hypoechoic ring surrounding a hemangioma was rare. In one case [6], histologic examination showed that the hypoechoic rim consisted of a thin fibrous pseudocapsule. Also, all three focal nodular hyperplasias (Fig. 6) and one of two hepatic adenomas in our series had a hypoechoic halo. To our knowledge, this sonographic feature has not been previously described for these rare tumors, and therefore no correlative histopathologic data are available. Because a halo was more common in benign focal nodular hyperplasias than in malignant hepatocellular carcinomas in our series, this area warrants further investigation.

One of four isoechoic and solid-appearing liver abscesses also had a hypoechoic rim and was interpreted as being malignant. After hemangiomas, focal fatty infiltration is the second most common hyperechoic benign liver lesion [2, 7]. It may seem remarkable that all nine focal fatty infiltrations in

our series were correctly classified as benign lesions because they did not have a halo (Fig. 10).

Six malignant tumors (two hepatocellular carcinomas, four metastases) were falsely classified as benign lesions because they did not have a halo (Fig. 11). Shinagawa et al. [8] found a peripheral hypoechoic rim in approximately 50% of all hepatocellular carcinomas. In our study, only two (33%) of six hepatocellular carcinomas had no hypoechoic halo. Only four (9%) of 43 liver metastases (two colonic adenocarcinomas, one pancreatic adenocarcinoma, one renal cell carcinoma) did not have a hypoechoic halo (Fig. 11). Thus, the hypoechoic halo is a frequent and important sonographic feature of isoechoic or hyperechoic liver metastases (Figs. 2-4). Our histopathologic analysis of the halo [4] showed that it correlated with an intratumoral rim of proliferating tumor cells.

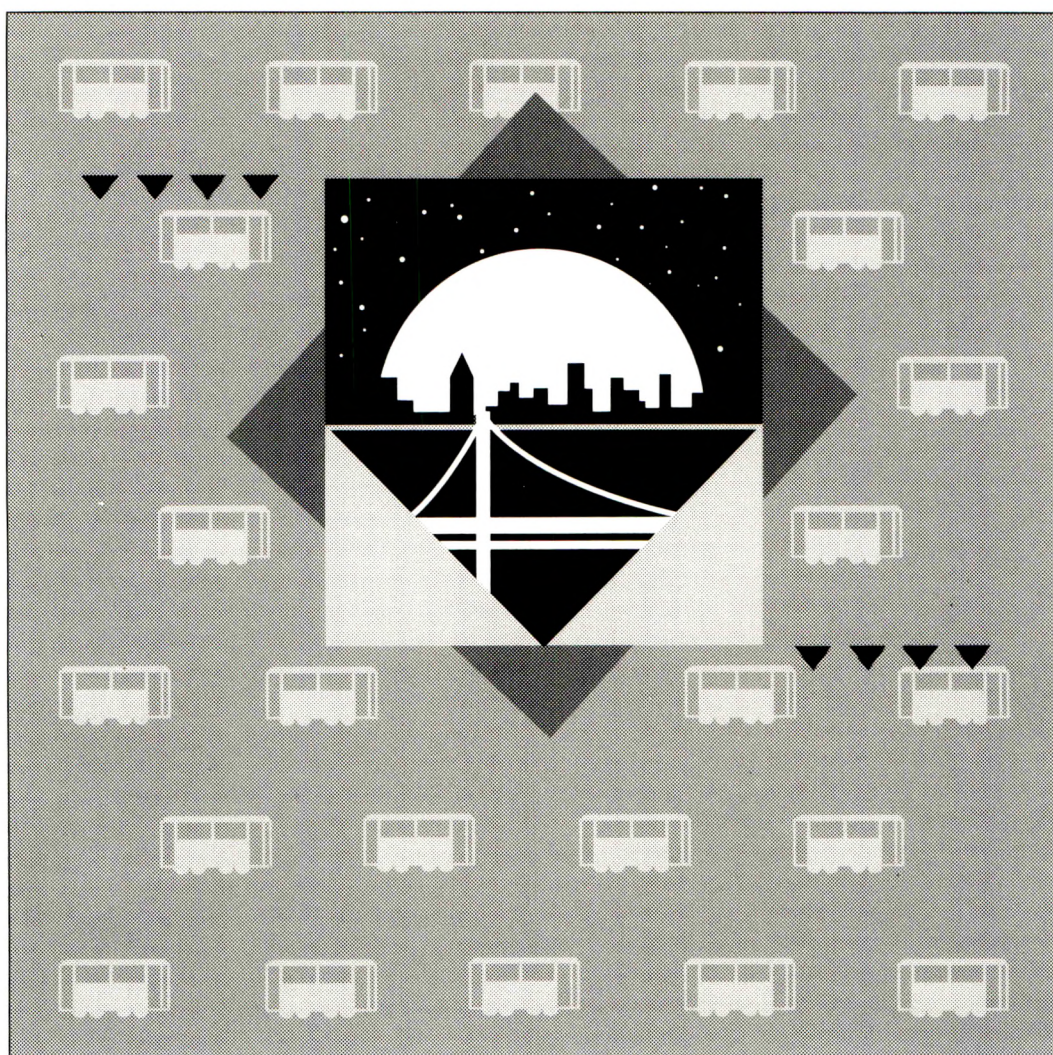
A recent review [9] on imaging of liver tumors concludes with a statement that sonography is of limited value as it cannot be used to distinguish benign from malignant lesions. This can, however, also be said for other imaging techniques such as CT and MR. In a CT study of liver lesions by Freeny et al. [10], only 54% of hemangiomas had a typical pattern of contrast enhancement; the remaining 46% of hemangiomas had the same pattern of enhancement as 77% of liver metastases. Even in the presence of a characteristic hemangioma type of contrast enhancement, the probability that a liver lesion in a patient with a known neoplasm represents a hemangioma is only 86% [10].

MR imaging is said to have an 85% accuracy in distinguishing hemangiomas from metastases [9]. Several studies have shown that the quantitative data (e.g., T1 and T2 values, lesion-to-liver signal-intensity ratios) of cavernous hemangiomas as a group are significantly different from those of metastases or hepatocellular carcinomas. However, a significant overlap occurs between the values of individual benign lesions and the values of malignant ones; thus, it is often not possible to identify a particular lesion [11]. In a recent trial by Itoh et al. [12], the lesion/liver signal-intensity ratio, the best quantitative criterion for distinguishing benign from malignant lesions, showed an overlap in 16 (31%) of 51 hemangiomas and in 14 (34%) of 41 metastases. To our knowledge, no prospective randomized study has been conducted to evaluate the usefulness of sonography, CT, and MR in the differential diagnosis of hepatic lesions. Thus, no objective scientific proof of the advantages of MR or CT over sonography in the differential diagnosis of hepatic tumors currently exists.

It is important to emphasize that we evaluated the usefulness of the halo sign in distinguishing benign from malignant isoechoic and hyperechoic lesions. Hypoechoic liver lesions, which generally are considered to be highly suggestive of a malignant tumor, were not included. One shortcoming in our study is the retrospective analysis of selected liver lesions with confirmed diagnoses. For this reason, our preliminary results on the accuracy of the halo sign for distinguishing malignant from benign lesions should be validated in a prospective randomized study. In our study, the proportion of hemangiomas with atypical sonographic features was unusually high (45%). Thus, under normal conditions with a nonselected patient group, the halo sign may actually provide better results for distinguishing hemangiomas from metastases.

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Pathologic Explanation for Hypoechoic Halo Seen on Sonograms of Malignant Liver Tumors: An In Vitro Correlative Study

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 Stefan Diederich¹
 Peter E. Peters¹
 Georg Edel²

OBJECTIVE. The purpose of this study was to evaluate the morphologic substrate of the hypoechoic halo seen on sonograms of malignant liver tumors.

MATERIALS AND METHODS. We used sonograms and pathologic examinations to evaluate 17 cadaveric livers with macroscopic tumors (three primary liver tumors, 14 metastases). During sonography (3.5 and 5.0 MHz), a representative section plane was marked, and the same section was examined histologically. Emphasis was placed on the architecture of the tumor and the morphology of the periphery of the tumor that could account for the hypoechoic halo seen on sonograms.

RESULTS. In 13 of 17 hepatic tumors, a hypoechoic halo was detected on sonograms. Histopathologic examination showed an intratumoral rim consisting of proliferating tumor cells in 12 cases and an extratumoral rim of compressed liver parenchyma in all 13 cases. A detailed comparison of sonographic and histopathologic findings showed that the hypoechoic halo corresponded to a greater concentration of tumor cells and areas of less marked fibrosis and necrosis in the periphery of the tumors. This occurred in 11 cases. In one case, histologic studies showed that the hypoechoic rim was caused by compressed liver parenchyma. In another case, the hypoechoic halo was caused by intratumoral (cellular peripheral zone of tumor) and extratumoral (compressed liver parenchyma) components. All four tumors without a halo at sonography were uniform histologically.

CONCLUSION. The sonographic halo seen on sonograms of malignant liver tumors seems to be caused predominantly by a zone of proliferating tumor in the periphery of the lesion.

AJR 159:1011-1016, November 1992

Sonograms of malignant liver tumors frequently show a peripheral hypoechoic rim known as the halo sign [1]. Although the exact frequency of this finding in malignant liver tumors has not been determined and a hypoechoic rim can also be visualized with benign hepatic lesions, it is generally accepted that the halo sign is suggestive of a malignant liver tumor [2]. The hypoechoic halo can be detected only when the tumor is isoechoic or hyperechoic compared with the liver. Previous authors [3, 4] have suggested that the halo may be caused by intratumoral tissue in the periphery of the tumor, whereas others [5] have thought that the finding is due to extratumoral tissue in the adjacent liver.

To clarify the pathologic basis for the sonographic findings, we compared postmortem sonograms and histopathologic sections of 18 liver tumors.

Materials and Methods

Sonograms of 35 cadaveric livers with macroscopic tumors were obtained 3-4 hr after autopsy. Before resection of the liver specimens at autopsy, the hepatic vessels and the common hepatic duct were ligated in order to keep air out of the liver.

Sonograms were inadequate in 14 of the 35 livers because of intrahepatic air bubbles due to autolysis or incomplete ligation of the hepatic vessels. Four livers with multiple, dissemi-

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nated, confluent metastases were excluded because a detailed comparison of sonographic and histopathologic sections of a single lesion was not possible.

The study included 17 tumors in 17 liver specimens. The tumors measured 1.0–10.5 cm in diameter, with 9 lesions smaller than 3 cm (Table 1). The histologic diagnoses of the tumors (three primary liver tumors, 14 hepatic metastases) are listed in Table 1.

Sonographic Evaluation

Sonograms were obtained with 3.5- and 5.0-MHz linear-array probes (LS 7000, Picker International, Munich, Germany). The liver specimen was placed in a bath containing physiologic (0.9%) saline.

The tumors were classified as hypoechoic, isoechoic, or hyperechoic depending on their echogenicity in relation to the surrounding liver parenchyma, and the presence or absence of a surrounding hypoechoic halo was recorded. A hypoechoic halo was defined as an area in the periphery of the tumor that was hypoechoic compared with the center of the lesion and surrounding liver parenchyma, regardless of the thickness of the rim. The inner and outer contours

and the internal structure of the hypoechoic halo were analyzed. Finally, the diameter of the liver tumor and the thickness of the halo were measured.

A representative sonographic section of the liver tumor was marked with two or three needles that perforated the whole organ. If the section plane had multiple lesions, the lesion of interest was marked with an additional needle.

Histopathologic Evaluation

After sonographic examination, a block of liver tissue containing the tumor was excised and fixed in 5% formalin for 24 hr. This preliminary fixation facilitated cutting the specimen in the selected section plane. After fixation, the slices were placed in 70% alcohol for 30 min and then photographed. For histologic study, the slices were fixed in 5% formalin for 8 weeks, embedded in paraffin wax, and stained with hematoxylin and eosin, elastica, periodic acid–Schiff (PAS), Giemsa, Ladewig, and Prussian blue stains.

The macroscopic, unstained sections of the liver were analyzed for the following: outer contour of the liver tumor; presence or

TABLE 1: Correlation of Sonographic and Histopathologic Findings in 17 Cases of Malignant Hepatic Tumor

Case No.	Histologic Diagnosis	Sonographic Findings			Thickness of Tumor Rim at Histopathology (mm)	
		Echogenicity	Tumor Diameter (cm)	Thickness of Halo (mm)	Intratumoral	Extratumoral
1	Breast carcinoma	Isoechoic	1.3	3.0	3.0	<1.0
2	Bronchogenic adenocarcinoma	Isoechoic	1.3	3.0	3.0	1.0
3	Hepatocellular carcinoma	Isoechoic	2.3	8.0	8.0	1.0
4	Adenocarcinoma of the colon	Isoechoic	3.5	3.0	3.0	<1.0
5	Bronchogenic squamous cell carcinoma	Isoechoic	3.8	8.0	— ^a	8.0
6	Cholangiocarcinoma	Hyperechoic	8.0	8.0	3.0	5.0
7	Adenocarcinoma of the colon	Hyperechoic	10.5	4.0	4.0	<1.0
8	Adenocarcinoma of the stomach	Hyperechoic	1.3	1.0	1.0	1.0
9	Bronchogenic oat cell carcinoma	Isoechoic	1.5	1.0	1.0	<0.5
10	Adenocarcinoma of the colon	Isoechoic	2.8	2.0	2.0	<1.0
11	Adenocarcinoma of the pancreas	Isoechoic	4.5	3.0	3.0	<1.0
12	Transitional cell carcinoma	Hyperechoic	4.5	2.0	2.0	<1.0
13	Bronchogenic oat cell carcinoma	Isoechoic	5.5	2.0	2.0	2.0
14	Bronchogenic squamous cell carcinoma	Hypoechoic	1.0	No halo	—	0.5
15	Cystadenocarcinoma of the pancreas	Isoechoic	1.2	No halo	—	—
16	Adenocarcinoma of the stomach	Hypoechoic	2.0	No halo	—	1.0
17	Hepatocellular carcinoma	Hypoechoic	6.0	No halo	—	—

^a No difference noted between peripheral and central portions of tumor.

absence of liver tissue compression or peritumoral fibrosis; tumor architecture, especially the presence or absence of an intratumoral peripheral rim; and degree of tumor necrosis. The diameter of the lesion and the thickness of a macroscopically visible intra- or extratumoral rim were determined.

In the next step, the stained macroscopic cross sections were analyzed by using the same criteria. Finally, the intra- or extratumoral rims detected macroscopically were examined histologically. Because the echogenicity of a lesion is related to its different components (vital tumor cells, connective tissue, necrosis, fatty degeneration, and blood vessels [5-9]), the proportions of the various components were calculated (e.g., tumor cells:connective tissue:necrosis = 60:20:20).

Finally, the sonographic and histopathologic findings were compared in order to evaluate the structure of the hypoechoic halo.

Results

Sonographic Findings

Of the 17 hepatic tumors, 10 were isoechoic, four were hyperechoic, and three were hypoechoic. In 13 lesions (nine isoechoic, four hyperechoic), a hypoechoic halo was clearly detected. The thickness of the halo was 1 mm in two lesions, 1-2 mm in three lesions, 2-3 mm in four lesions, and more than 3 mm in four lesions (Table 1). In four liver tumors, no hypoechoic halo could be detected.

Histopathologic Findings

Liver tumors with a hypoechoic halo.—In 12 of 13 tumors that had a halo on sonograms, a peripheral *intratumoral* rim could be detected histopathologically. The tissue composition of the rim was clearly different from that of the central portions of the lesion. In all 12 cases, this intratumoral rim represented

solid tumor without necrosis. In the central parts of the lesion, tumor cells were more sparse and connective tissue was more abundant (Fig. 1). In addition, the central parts of four tumors contained areas with nonliquefactive necrosis.

The thickness of the peripheral intratumoral rim was 1 mm in two lesions, 1-3 mm in eight lesions, and more than 3 mm in two lesions (Table 1). In one lesion that was 3.8 cm in diameter (case 5), no difference in histologic architecture was noted between the most peripheral and central portions of the tumor. In this tumor, the proportions of vital tumor cells, fibrosis, and nonliquefactive necrosis (75:10:15) were essentially uniform in all parts of the lesion (Fig. 2).

In all 13 cases, an *extratumoral* rim surrounding the lesion could also be detected histopathologically (Figs. 1 and 2). In 11 cases, the extratumoral rim predominantly represented compressed liver parenchyma (Figs. 1 and 2). In two cases, the peritumoral rim of compressed liver parenchyma contained hepatocytes with fatty degeneration. The peritumoral rim reflected sinusoidal dilatation in one case and noncompressed liver parenchyma in another. The thickness of the extratumoral rim was 0.5-1.0 mm in 10 lesions, 1-2 mm in one lesion, and more than 2 mm in two lesions (Table 1).

Liver tumors without a hypoechoic halo.—In the four tumors that showed no halo on sonograms, no intratumoral rim could be recognized histologically. All four had an essentially uniform histologic architecture in terms of the proportions of vital tumor, fibrotic, and necrotic tissue in the peripheral and central parts of the lesion. In two of the four lesions, extratumoral rims (0.5 and 1.0 mm in diameter) were detected histologically; these represented compressed liver parenchyma in both cases. One of the remaining two lesions (hypoechoic hepatocellular carcinoma) was surrounded by a fibrous capsule. In the other lesion (metastasis of a pancreatic cystadenocarcinoma), the tumor border could not be deter-

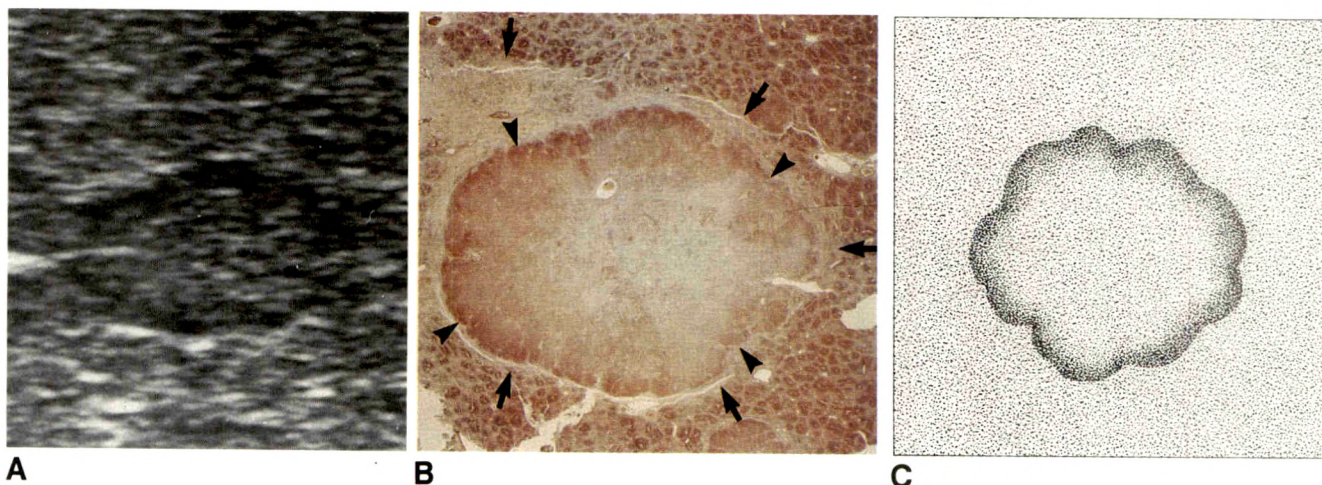


Fig. 1.—Metastasis with a hypoechoic halo corresponding to an intratumoral rim (adenocarcinoma of colon).

A, Sonogram (5.0 MHz) shows a 3.5-cm isoechoic lesion with a 3-4 mm thick hypoechoic halo. Note poorly defined inner margin and sharply demarcated outer contour of hypoechoic halo.

B, Photomicrograph of histologic section shows that hypoechoic halo corresponds to intratumoral peripheral layers of tumor cells (arrowheads). Central parts of lesion have fewer tumor cells and more abundant fibrous tissue with areas of nonliquefactive necrosis. Outer border of tumor (arrowheads) is sharply demarcated and slightly lobulated. Lesion is surrounded by a rim of compressed liver parenchyma 1-7 mm in diameter (arrows) that was not detected on sonogram. (Giemsa stain)

C, Drawing shows characteristic morphologic features of "intratumoral" type of halo.

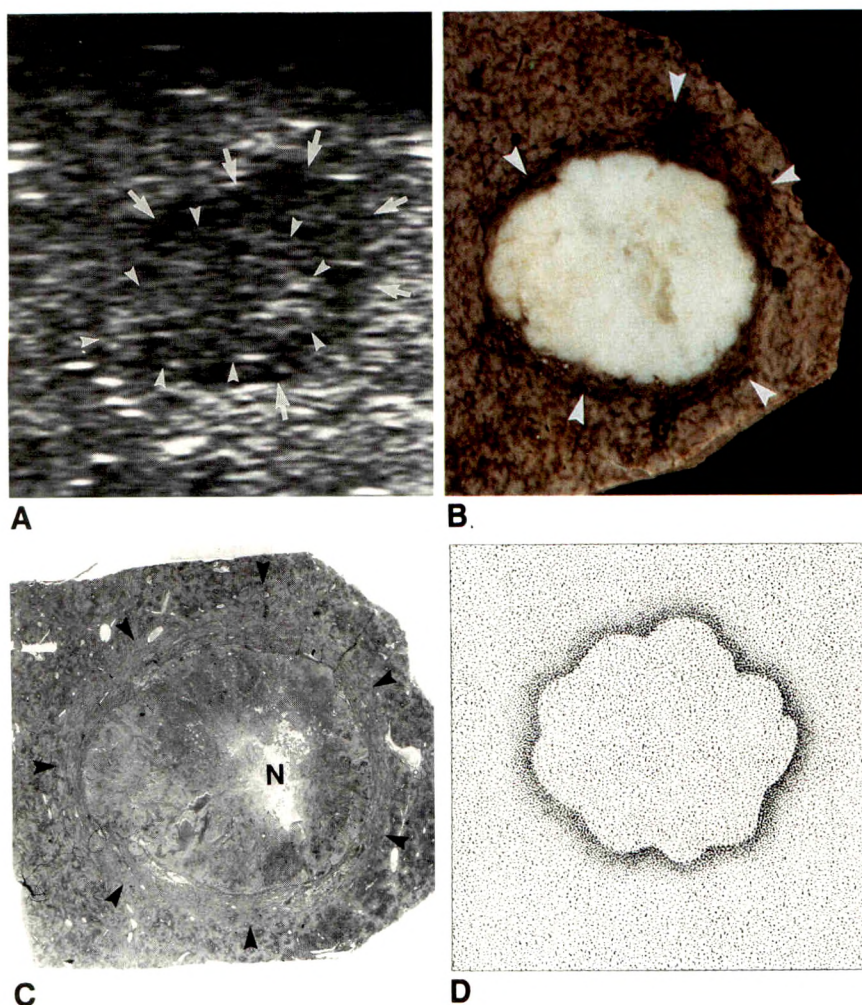


Fig. 2.—Metastasis with a hypoechoic halo corresponding to an extratumoral rim of compressed liver parenchyma (bronchogenic squamous cell carcinoma).

A, Sonogram (3.5 MHz) shows a 3.5-cm isoechoic lesion surrounded by a hypoechoic halo (arrows) of variable thickness (up to 8 mm). Note concave lobulated inner contour of halo (arrowheads).

B, Pathologic specimen shows a tumor with rather homogeneous internal architecture and convex lobulated outer contour surrounded by a broad rim of compressed liver parenchyma (arrowheads).

C, Photomicrograph of histologic section shows uniform tumoral architecture and a rim of compressed liver parenchyma (arrowheads). N = area of central necrosis. (PAS stain)

D, Drawing shows characteristic morphologic features of extratumoral type of halo.

mined exactly because of diffuse infiltration of the surrounding liver parenchyma.

Correlation of Sonographic and Histopathologic Findings

Liver tumors with a hypoechoic halo.—In seven of 13 cases, we found an unequivocal correlation between the thickness of the hypoechoic halo on sonograms and the thickness of the tumoral rim on histologic sections (Table 1, cases 1–7). In five of these seven cases, the thickness of the hypoechoic halo (3–8 mm) was absolutely identical to the thickness of the intratumoral rim (Fig. 1). The maximum diameter of extratumoral rims detected histopathologically in these five cases (compressed liver parenchyma) was 1.0 mm.

In one of seven cases (case 5), a broad hypoechoic halo 4–8 mm in diameter on sonograms corresponded to an equally thick extratumoral rim of compressed liver parenchyma on histologic sections (Fig. 2). No intratumoral rim could be detected in this lesion.

In another case (case 6), a lesion with a hypoechoic halo measuring 8 mm in diameter on sonograms had a 3-mm intratumoral rim and a 5-mm extratumoral rim (compressed liver parenchyma) on histologic sections (Fig. 3).

In six lesions that had thin hypoechoic halos (1–3 mm in diameter) on sonograms (Table 1, cases 8–13), no histopathologic correlation was possible because the thickness of the intratumoral rim (≤ 2 mm) was similar to that of the extratumoral rim (≤ 2 mm). To solve this problem, we further analyzed the configuration of the tumor border and the morphology of the intra- and extratumoral rims on histologic sections and compared the findings with the morphologic characteristics of the hypoechoic halo on sonograms. The results showed that the hypoechoic halo was caused by an intratumoral rim in 11 cases (Fig. 1), by an extratumoral rim in one case (Fig. 2), and by both intra- and extratumoral components in one case (Fig. 3).

A halo caused by an intratumoral rim was characterized sonographically by a poorly defined inner contour and a sharply demarcated, convex, lobulated outer contour. The decreasing echogenicity of the halo toward the outer contour corresponded histologically to an increasing concentration of tumor cells at the periphery (Fig. 1). In contrast, the halo caused by an extratumoral rim had a poorly defined outer contour and a sharp, concave, lobulated inner contour on sonograms, which was caused by the subjacent convex lobulated border of the tumor (Fig. 2). Furthermore, this type

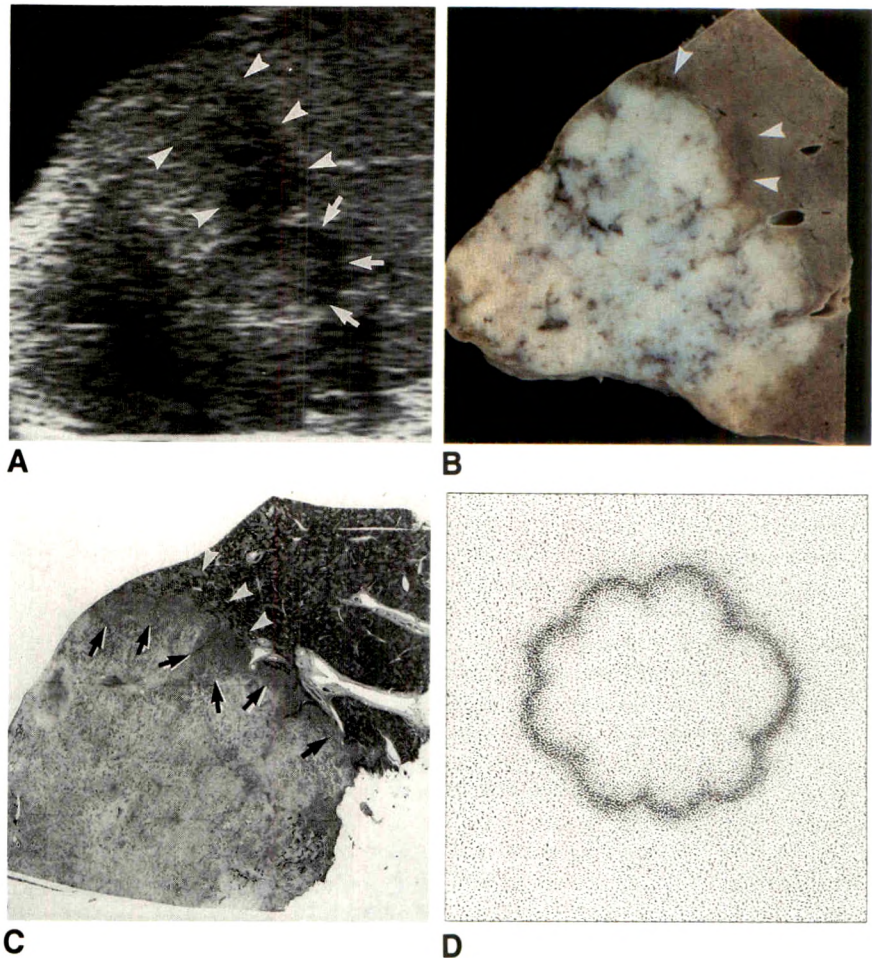
Fig. 3.—Peripheral cholangiocarcinoma with hypoechoic halo corresponding to intra- and extra-tumoral rims.

A, Sonogram (3.5 MHz) shows a predominantly hyperechoic lesion. Hypoechoic halo has variable features: its lower portion is thin with a sharp, lobulated outer contour (arrows) and a poorly defined inner border (intratumoral type of halo); its upper portion, however, is clearly thicker (arrowheads), with a poorly defined border.

B, Pathologic specimen shows no compression of liver parenchyma at lower margin of tumor and marked compression of surrounding liver parenchyma at upper border of lesion (arrowheads).

C, Low-power photomicrograph of histologic section shows an intratumoral rim (not seen on pathologic specimen, B) consisting of proliferating tumor cells (arrows) and compressed liver parenchyma at upper part of border (arrowheads) that is better seen on pathologic specimen (B).

D, Drawing shows characteristic morphologic features of mixed type of halo.



of halo showed a decreasing echogenicity toward its inner border. The hypoechoic halo caused by both intra- and extra-tumoral components had poorly defined inner and outer contours and an increasing intensity from both sides (Fig. 3).

Liver tumors without a hypoechoic halo.—Three of four tumors without a halo were homogeneously hypoechoic (Table 1, cases 14, 16, and 17). The hypoechoic structure of these lesions correlated histologically with solid tumor tissue (proportion of tumor cells, 60–90%) with a uniform architecture. On histologic examination, two of the three hypoechoic tumors were surrounded by an extratumoral rim of compressed liver parenchyma that could not be delineated sonographically.

The remaining one tumor without a halo, a metastasis of a cystadenocarcinoma of the pancreas (case 15), was isoechoic and could barely be seen on sonograms (5.0 MHz). Histologic examination of the metastasis showed no intra- or extratumoral rims and diffuse infiltration of liver parenchyma.

Discussion

The hypoechoic halo observed on sonograms of isoechoic or hyperechoic hepatic lesions represents tissue with a composition and acoustic impedance that differ from those of

tissue at the center of and surrounding the lesion. The tissue may theoretically lie inside or outside the tumor margins (intra- or extratumoral).

In our cases, the hypoechoic halo corresponded primarily to an intratumoral rim (11 of 13 tumors with a hypoechoic halo). Histologic examination showed that this rim consisted of solid tumor tissue without necrosis and had a loose reticular collagen framework. This most peripheral part of the tumor may represent the "zone of proliferation." Histologically, the concentration of tumor cells in the zone of proliferation increased gradually from the poorly defined inner border toward the sharply demarcated, lobulated outer border (Fig. 1). A close correlation was noted between the histologic characteristics of the zone of proliferation and the morphology of the corresponding hypoechoic halo on sonograms. The halo had a poorly defined inner contour, a sharp, lobulated outer contour, and a decreasing echogenicity toward the outer contour (Fig. 1).

In only one of 13 cases, the hypoechoic halo corresponded solely with an extratumoral rim, which essentially consisted of compressed liver tissue and was 2–8 mm thick (Fig. 2). In this case, the echogenicity of the halo decreased toward its sharp inner, concave, lobulated border. Histologic examination showed that the shape of the inner border of the extra-

tumoral rim was caused by the adjacent convex, lobulated outer boundary of the tumor (Fig. 2). The decreasing echogenicity of this type of halo toward the center may be due to an increasing degree of compression of liver parenchyma.

The presence of both intra- and extratumoral rims may indicate a "mixed" type of halo, which would have morphologic features of both types. Indeed, we saw such a case. This mixed type of halo, which corresponded histologically to a combination of intra- and extratumoral rims, had poorly defined inner and outer contours and a decreasing echogenicity toward both margins on sonograms (Fig. 3).

The distinction between the sonographic appearance of an intratumoral vs extratumoral rim may have practical applications. As an area for future research, it would be very interesting if it could be shown that in benign tumors with a sonographic halo, the halo is more likely due to an extratumoral rim than to an intratumoral rim. However, it is likely that larger benign tumors may have areas of central necrosis and therefore also have an intratumoral rim.

Accurate sonographic and pathologic correlation of small anatomic structures (1 mm in diameter) based on size alone has been difficult because of slight differences in section planes and changes in the size and shape of the specimens during preparation (excision and preliminary fixation). Other morphologic criteria (e.g., outer and inner contours and internal structure of the hypoechoic rim) had to be included in our study to allow exact correlation of structures seen on sonograms and histologic sections.

We found a close correlation between regional echogenicity and histologic structure. Earlier studies [8, 9] that correlated sonographic and histologic findings showed that solid tumor tissue without necrosis is seen on sonograms as a hypoechoic area, presumably because of the lack of any structure within the tumor that might serve as a reflective source for echoes. In addition, it is well known that the echogenicity of tumor tissue increases with increasing fibrosis, nonliquefactive necrosis, and fatty metamorphosis [7-9]. In light of these findings, it appears reasonable to state that the zone of proliferation with its high tumor cell content is visualized sonographically as a hypoechoic halo and that the central portions of the tumor, which have undergone fibrotic change and/or nonliquefactive necrosis, appear isoechoic or hyperechoic. It is difficult to explain how compressed and atrophic liver tissue (which was the sole histologic correlate of the halo in only one lesion in our study) can appear hypoechoic [5], and, in fact, sometimes it does not (Fig. 1).

Our results contrast with those of Marchal et al. [5], who used 7.5- and 10.0-MHz transducers and examined mostly small metastases ($n = 20$). In their study, all 12 metastases that had a hypoechoic halo on sonograms showed a thin peritumoral rim of compressed liver parenchyma (1.5 mm in diameter) on histologic examination. As all small metastases histologically were uniform in structure, the authors concluded that peritumoral compression of liver parenchyma is probably the major cause of the halo.

Differences in the sizes of lesions (medium vs small), sonographic probes (3.5 and 5.0 vs 7.5 and 10 MHz), and primary

tumors may account for the discrepancies between the two studies. Although the article by Marchal et al. [5] includes no precise data on lesion size, most of the illustrations show lesions less than 1 cm in diameter. Such lesions and their thin hypoechoic halo (approximately 1 mm thick) might not be visualized on percutaneous sonograms [10]. Thus, the use of 3.5- and 5.0-MHz transducers and the size of the lesions in our study are more likely similar to what occurs in the normal clinical situation. Unlike those described by Marchal et al., most lesions in our study showed a clear difference in tissue composition and histologic architecture between their peripheral and more central portions. Although the number of cases in our study is too small for some statistically significant conclusions, an intratumoral rim is more likely to be seen in a larger lesion that has undergone central necrosis. At histologic examination, only four of seven tumors 2.0 cm or less in diameter but eight of 10 tumors larger than 2.0 cm in diameter displayed an intratumoral rim (Table 1). Certainly, the degree of zonal variation in histologic structure also differs depending on the origin of the primary tumor. Most liver metastases in our study were adenocarcinomas. Marchal et al. gave no data on the origin of the hepatic metastases they studied.

To our knowledge, no general consensus exists on the thickness of the hypoechoic halo. In the study of Marchal et al. [5], the hypoechoic halos were generally thin (≤ 1.5 mm thick). However, in most cases reported in the literature, the hypoechoic halo was usually several millimeters thick. In our study, no upper limit was set for the thickness of the halo. This approach is supported by the results of the histologic examinations, which showed identical tissue characteristics for hypoechoic halos in lesions with either thin (≤ 3 mm, $n = 9$) or thick (> 3 mm, $n = 4$) hypoechoic rims.

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Pictorial Essay

Differential Diagnosis of Hyperintense Liver Lesions on T1-Weighted MR Images

Michael J. Lee,¹ Peter F. Hahn, Sanjay Saini, and Peter R. Mueller

Because most liver lesions are hypointense with respect to liver on T1-weighted MR images, lesions hyperintense to liver form a special diagnostic category. Truly hyperintense lesions contain a substance that shortens the lesion's T1, thus increasing its signal intensity. Relative hyperintensity occurs in lesions surrounded by liver that has diminished signal intensity (Fig. 1). In this essay, we present examples of lesions hyperintense to liver on T1-weighted images, explain their unique appearance, and provide clues for differentiating among them. T1-weighted spin-echo (SE) images (275/14 [TR/TE]) were acquired with a 0.6-T MR unit (Toshiba, General Electric Medical Systems, Milwaukee, WI) in all patients.

Truly Hyperintense Lesions: Endogenous Substances

Fat

Steatosis shortens the T1 relaxation time of tissues. Some hepatocellular carcinomas and adenomas undergo fatty degeneration and appear hyperintense on T1-weighted MR images (Fig. 2). Rounded focal fatty deposits may be mistaken for hyperintense metastases [1] (Fig. 3). Other lesions that may appear hyperintense on T1-weighted images because of fat content include hepatic lipomas and surgical defects that are packed with omental fat.

Blood

Soon after hepatic hemorrhage, hematomas appear heterogeneously hyperintense because of their methemoglobin

content or, if a fluid-fluid level develops, high signal occurs in the dependent layer. Later, space-occupying hematomas often develop a bright ring where methemoglobin collects at the periphery [2] (Fig. 4).

Hemorrhage in solid tumors produces bright streaks or heterogeneous hyperintensity on T1-weighted images (Fig. 5). The T1 shortening observed in liver tumors after biopsy or interventional therapy [3] may also be due to hemorrhage.

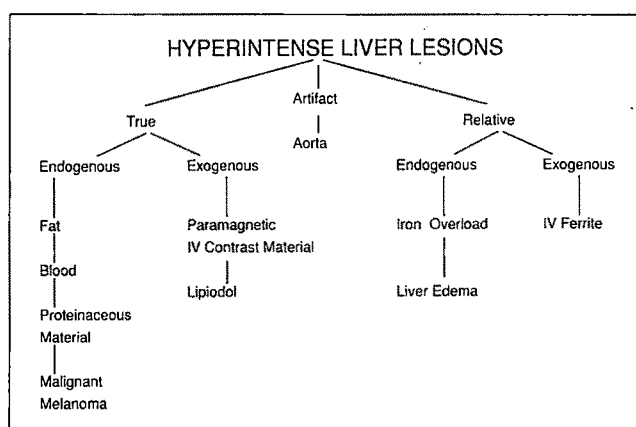
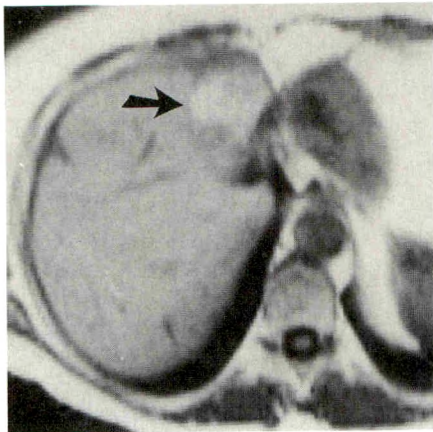


Fig. 1.—Causes of hyperintensity of liver lesions on T1-weighted MR images. True or relative hyperintensity of a lesion on T1-weighted images can be subdivided into endogenous and exogenous categories, according to whether the substance causing change in signal intensity is naturally occurring or has been injected as a contrast agent.

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A



B

Fig. 2.—Patient with cirrhosis and hepatocellular carcinoma.
A, Hepatocellular carcinoma (arrow) is hyperintense relative to surrounding tissue on this T1-weighted SE MR image (275/14) because of fatty degeneration.
B, T2-weighted SE MR image (2350/180) shows lesion to have intermediate signal intensity similar to that of spleen, indicating its solid nature. This helps to differentiate this hepatocellular carcinoma from a hematoma, which also may have high signal intensity on T1-weighted images.

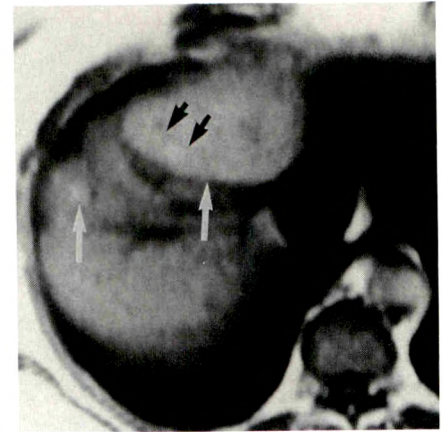


Fig. 3.—Asymptomatic patient with multiple hyperintense liver lesions (white arrows) on T1-weighted SE MR images (275/14). Percutaneous biopsy revealed fatty infiltration of liver. Absence of mass effect is indicated by faintly seen blood vessel within larger mass (black arrows). All lesions in this patient were hyperintense relative to surrounding tissue.

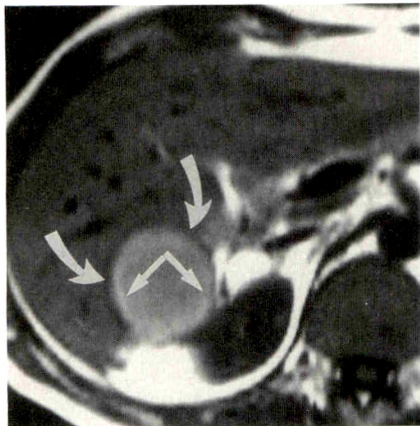


Fig. 4.—Chronic hematoma in a patient with leukemia after a blind right-sided thoracentesis. T1-weighted MR image (275/14) shows concentric rim sign, a hypointense outer rim due to deposition of iron particles (curved arrows), and an inner hyperintense rim due to methemoglobin (straight arrows). This appearance may be seen after tumor biopsy but is rarely seen in tumors de novo. Slight hepatic iron overload decreases signal intensity of liver to a level almost equal to signal intensity of spleen.



Fig. 5.—Patient with pathologically proved hemorrhage into an ovarian metastasis. T1-weighted SE MR image (275/14) shows heterogeneously hyperintense lesion with mass effect, but no capsule in right lobe of liver. This could be mistaken for a hematoma. However, T2-weighted images confirmed solid nature of mass, increasing likelihood of tumor hemorrhage.



Fig. 6.—Patient with multiple metastases from malignant melanoma. On T1-weighted SE MR images (275/14), some lesions are hyperintense (curved arrows) relative to liver while others are hypointense (straight arrows). At autopsy, liver lesions exhibited various degrees of melanin content, suggesting that melanin concentration may account for various signal characteristics of metastases in this patient. No excess of iron was found.

Hepatic artery aneurysms may appear hyperintense on T1-weighted images because of the varied signal characteristics of clotted or flowing blood.

Proteinaceous Material

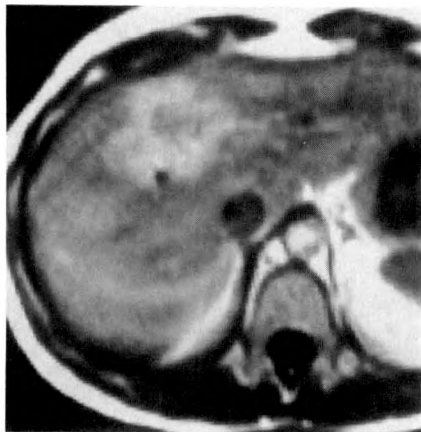
The diamagnetic effect of proteinaceous material leads to T1 shortening in the dependent layer of fluid-fluid levels within abscess cavities or hematomas. This is due to an increased concentration of hydrated protein macromolecules.

Melanoma Metastases

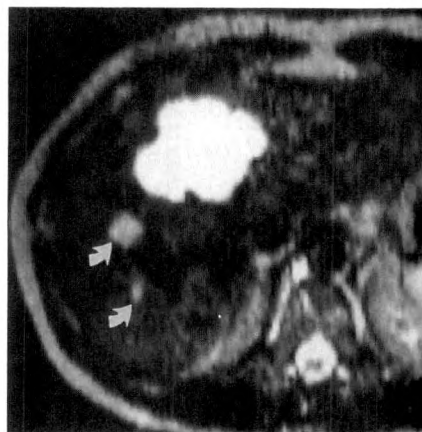
Melanoma metastases may exhibit T1 shortening that causes an isointense or hyperintense appearance. It is unclear if this is due to a paramagnetic effect of deposited melanin within the tumor (Fig. 6).

Truly Hyperintense Lesions: Exogenous Substances

Paramagnetic IV contrast agents such as gadopentetate dimeglumine shorten T1 relaxation time. Lesions taking up



A



B

Fig. 7.—Patient with one large and many small hemangiomas.

A, T1-weighted SE MR image (275/14) shows a hemangioma after administration of gadopentetate dimeglumine. Hemangioma is hyperintense relative to liver because of paramagnetic effect of gadopentetate dimeglumine. As on CT scans, hemangioma is filling in from periphery (which is hyperintense) to center (which is still hypointense relative to surrounding tissue). Gadopentetate dimeglumine uptake by hemangiomas is delayed compared with uptake by metastases.

B, T2-weighted SE MR image (2350/180) confirms diagnosis of one large and two small hemangiomas (arrows) with long T2 of lesions producing "light-bulb" type of hyperintensity.

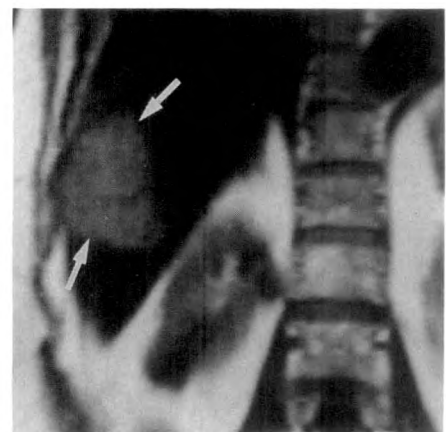


Fig. 8.—Hepatocellular carcinoma in a patient with hemochromatosis. Although lesion (arrows) is hyperintense compared with liver on T1-weighted SE MR image (275/14), appearance is produced by iron-overloaded, hypointense liver, which is even darker than spleen. Hepatocellular carcinoma appears hyperintense because it contains no deposited iron compared with remainder of liver. Multiple renal cysts are present.

the contrast material earlier, later, or more intensely than surrounding liver appear hyperintense if imaged at the proper time (Fig. 7). Lipiodol, which is an iodinated fatty acid-based contrast agent infused into the hepatic artery to enhance CT detection of multifocal hepatomas, produces lesion hyperintensity on T1-weighted MR images because of its fatty acid composition.

Relatively Hyperintense Lesions: Endogenous Substances

Hepatic Iron Overload

Excess iron deposition in the liver causes the liver to become lower in signal intensity on both T1- and T2-weighted images owing to a decrease in T2 relaxation time. Tumors (characteristically hepatocellular carcinoma) arising in such livers appear hyperintense compared with the surrounding low-signal-intensity liver (Fig. 8). Regenerating nodules in cirrhotic livers also may appear hyperintense relative to liver on T1-weighted MR images [4]. The reason for this is unclear but may be related to diffuse iron deposition in the surrounding cirrhotic liver.

Liver Edema

Hepatic congestion prolongs the T1 relaxation time of affected liver parenchyma because of excess tissue water. Lesions in edematous liver will consequently appear more intense than the surrounding hypointense liver (Fig. 9).

Relatively Hyperintense Lesions: Exogenous Substances

Superparamagnetic iron particles (ferrite) injected IV are taken up by the reticuloendothelial system and cause marked hypointensity of the liver and spleen. Tumors do not take up these iron particles and consequently appear hyperintense

relative to the dark-background liver on T1-weighted MR images (Fig. 10).

Artifact

Ghosting artifact from blood flow in adjacent large vessels can displace signal from the flowing blood outside the vessel in the phase-encoded direction. This may simulate a hyperintense liver lesion (Fig. 11).

Differential Diagnosis

First distinguish true T1 shortening of a lesion from a relative decrease in signal intensity of the surrounding liver by comparing the signal intensity of the liver with that of the spleen. On heavily T1-weighted MR images, the liver should be hyperintense relative to the spleen, but when the liver is overloaded with iron or congested or when iron oxide particles have been administered, the signal intensity of the liver is reduced (Figs. 8–10). Difficulties may arise when using this approach in patients with severe iron overload, as the spleen may be equally hypointense relative to the liver.

If a lesion is truly hyperintense then history-taking should reveal exogenous causes (Lipiodol and IV administration of paramagnetic contrast material). Gadolinium compounds now in common use cause only a transient shortening of lesion T1, but Lipiodol remains in some hepatocellular carcinomas for a long time. Choice of a fat-sensitive pulse sequence can often show fat to be the short-T1 material present.

It may not be possible to identify the T1-shortening material in all cases. However, it is important to differentiate benign from malignant lesions. Fatty degeneration in hepatocellular carcinoma can be differentiated from focal fatty infiltration by the presence of a hypointense tumor capsule, central necrosis, mass effect, or venous invasion (Fig. 9). Melanoma metastases and hemorrhagic lesions remain bright on fat-suppressed T1-weighted images compared with rounded fatty deposits.

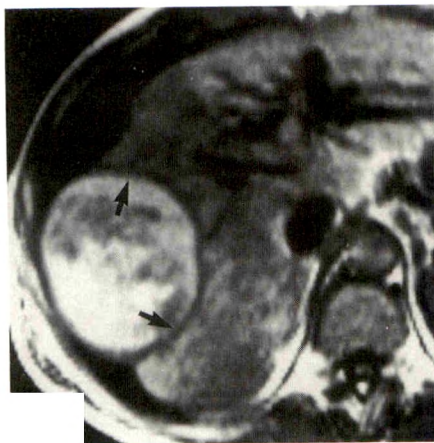
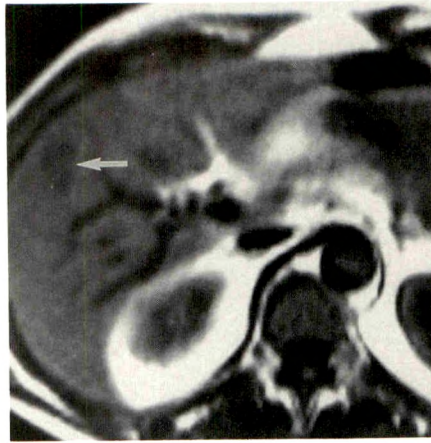
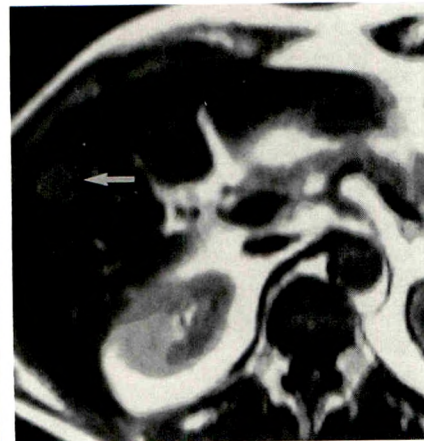


Fig. 9.—Patient with cirrhosis, hepatocellular carcinoma, and hepatic venous invasion causing diffuse edema of right lobe of liver. Hepatocellular carcinoma appears hyperintense on T1-weighted SE MR image (275/14) because of a combination of true and relative causes. Fatty degeneration within hepatocellular carcinoma is causing T1 shortening of lesion while low signal intensity of congested right lobe of liver augments lesion's hyperintensity. Note similar signal intensities of right lobe of liver and spleen, compared with more normal signal intensity of left lobe of liver. Hepatocellular carcinoma also shows mass effect (bulging liver capsule) and a hypointense capsule (arrows), differentiating this lesion from focal fatty infiltration.



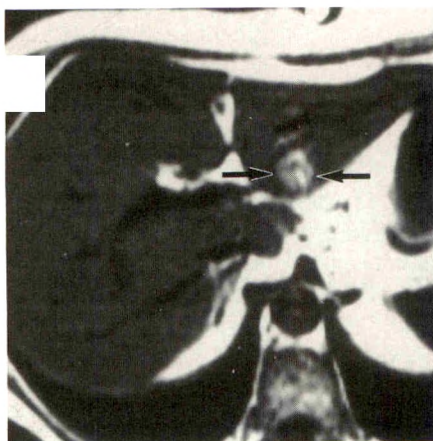
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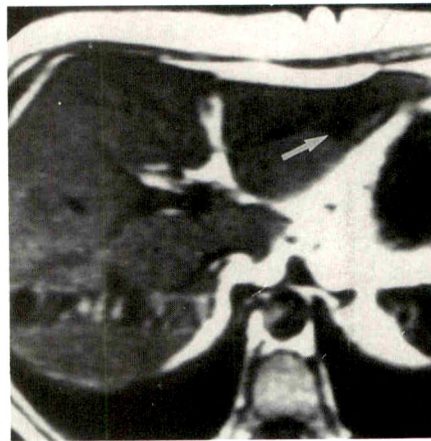
B

Fig. 10.—A patient with metastatic colonic carcinoma before and after IV administration of ferrite. A, T1-weighted SE MR image (275/14) shows single colonic metastasis (arrow), which is hypointense relative to normal liver.

B, After ferrite administration, lesion has become hyperintense (arrow) because it has not taken up injected iron particles while surrounding liver has. Shortening of liver T2 produced by iron particles diminishes liver signal intensity, even on T1-weighted images.



A



B

Fig. 11.—A hyperintense liver lesion created by artifact from flowing blood in aorta.

A, T1-weighted SE MR image (275/14) shows a hyperintense lesion in left lobe of liver within ghosting artifact produced from flowing blood in aorta (arrows).

B, T1-weighted SE MR images (275/14) was repeated after first changing phase-encoding gradient to horizontal. Hyperintense lesion is no longer present. This artifact is due to phase displacement of signal from blood flowing in aorta. Incidentally noted is a small hemangioma (arrow) in left lobe of liver.

Further information for differentiating benign from malignant lesions can be obtained from T2-weighted images. T2-weighted images may make subtle iron overload obvious, confirming an area of T1 hyperintensity to be a tumor focus surrounded by iron-overloaded liver. T2-weighted images also may help differentiate a melanoma metastasis from focal fatty infiltration. The heavy paramagnetic T1 shortening, seen in some melanoma metastases, can be associated with T2 shortening, making melanoma metastases occasionally appear hypointense with respect to liver on T2-weighted images. Focal lesions due to fatty infiltration will never exhibit such T2 shortening. T2-weighted images also may show additional lesions in patients in whom only a solitary hyperintense lesion is seen on T1-weighted images. This helps to differentiate multifocal melanoma metastases from a solitary lesion such

as a hematoma. Presence of a T1-hyperintense ring that is isointense with the center of the lesion on T2-weighted images indicates hematoma; this degree of organization rarely occurs in tumor hemorrhage.

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Case Report

Focal Ischemic Necrosis of the Liver Associated with Cirrhosis: Radiologic Findings

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Massive liver infarction is rare, but focal ischemic infarction of cirrhotic liver has been reported [1–3]. Edmondson [4] named such a lesion *anoxic pseudolobular necrosis*. This disorder is often not suspected clinically or radiologically, but is detected incidentally at autopsy. To our knowledge, the radiologic findings of this disease have not been reported. We describe the imaging findings in a patient with focal ischemic necrosis of a cirrhotic liver, which was resected surgically because hepatocellular carcinoma was suspected.

Case Report

An asymptomatic 66-year-old woman with liver cirrhosis was periodically examined with sonography and CT. Laboratory examination on admission showed leukopenia ($2500/\text{mm}^3$ [$2.5 \times 10^9/\text{l}$]), thrombocytopenia ($72 \times 10^3/\text{mm}^3$ [$72 \times 10^9/\text{l}$]), and mild liver injury (aspartate aminotransferase level, 126 U/l; alanine aminotransferase level, 110 U/l). Tests for hepatitis B surface antigen and antibody were negative, but a test for hepatitis C virus antibody was positive. The serum level of α -fetoprotein was slightly elevated at 46.4 ng/ml (46.4 $\mu\text{g/l}$), but the level of PIVKA-II (protein induced by vitamin K antagonists) was within normal limits.

Sonography revealed a hypoechoic nodular lesion measuring up to 1.5 cm in diameter at the surface of the liver adjacent to the gallbladder (Fig. 1A); this lesion had not been detected 3 months earlier. The nodule was seen as a subtle low-density area on contrast-enhanced CT scans. MR imaging showed a lesion that was hyperintense relative to the surrounding liver (Figs. 1B and 1C). Selective celiac angiography showed fine neovascularity in the arterial phase and round tumor stain with centrally decreased radiopacity in the capillary phase. CT scans obtained during arterial portography showed decreased portal blood perfusion (Fig. 1D).

Hepatocellular carcinoma was suspected on the basis of these findings, and the nodule was subsequently resected (Fig. 1E). Microscopically, several irregularly shaped foci of coagulative necrosis were observed with granulation tissue containing numerous small vessels. The surrounding liver showed mixed nodular cirrhosis. A normal trabecular pattern was observed within the necrosis, and reticulin fibers were regularly found within the stroma by the silver impregnation method. No viable cells were detected within the necrotic area. Tiny necrotic foci also were found in the surrounding cirrhotic liver. Histopathologically, these foci showed the characteristic appearance of so-called anoxic pseudolobular necrosis.

Discussion

Edmondson [4] described ischemic necrosis of advanced cirrhosis and named it anoxic pseudolobular necrosis. This disease is characterized by coagulative necrosis that involves one or more pseudolobules, especially their central zones. It has been claimed that this disease usually follows massive gastrointestinal hemorrhage and shock. Other investigators [1–3] have described similar patchy infarctions observed at autopsy in patients with liver cirrhosis or liver carcinoma, most of whom died of shock caused by gastrointestinal hemorrhage or rupture of the tumor.

Pathologically, true liver infarction is rare, because a dual blood supply is present. It is presumed that a sudden reduction in the portal and arterial flow after blood loss and shock induces an ischemic state in livers showing poor portal supply and inadequate compensation from arteries. Such livers are more likely to become ischemic because of diversion of blood flow by neoplasms or tumor thrombus and narrowing of the

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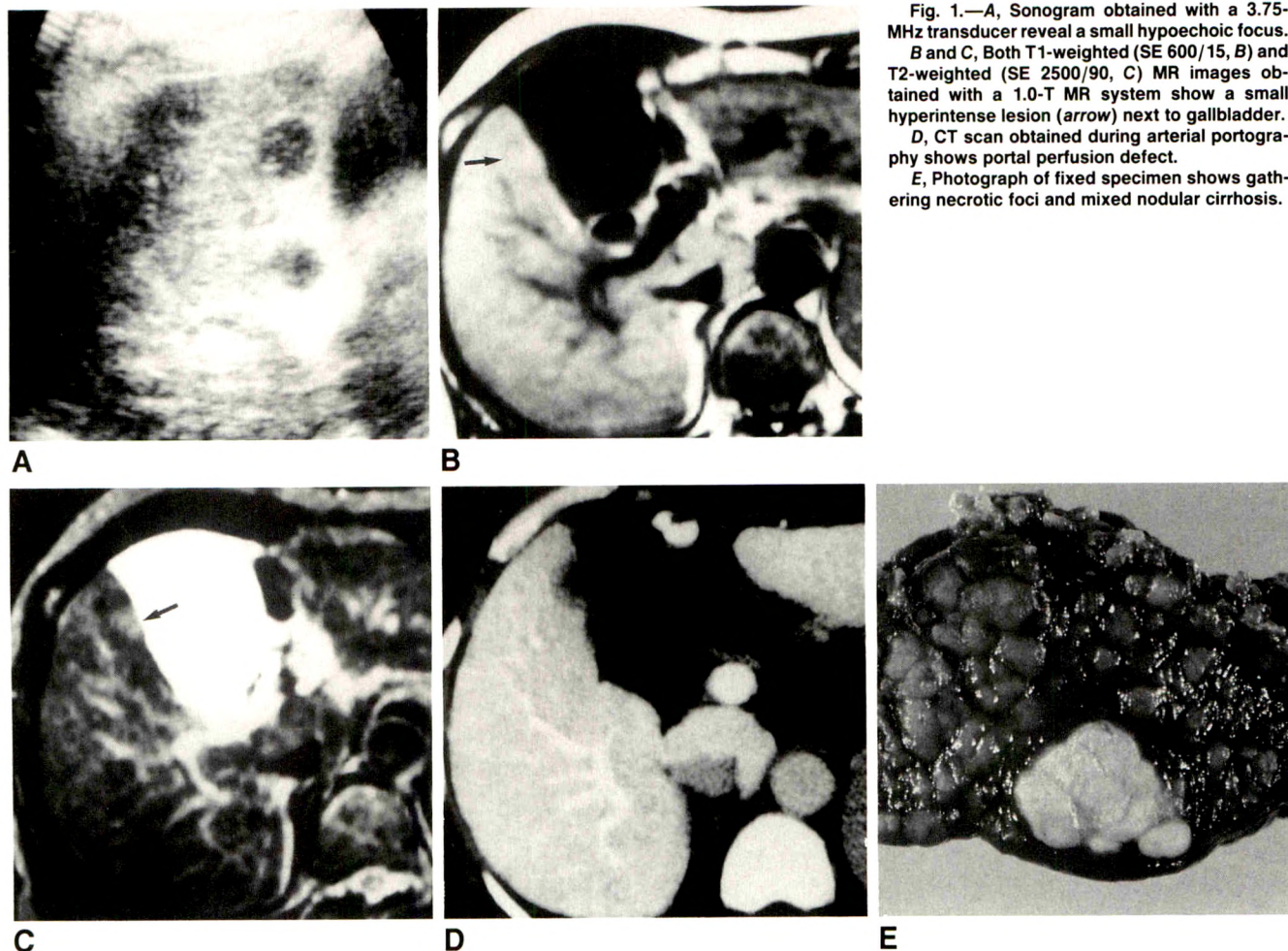


Fig. 1.—A, Sonogram obtained with a 3.75-MHz transducer reveal a small hypoechoic focus. B and C, Both T1-weighted (SE 600/15, B) and T2-weighted (SE 2500/90, C) MR images obtained with a 1.0-T MR system show a small hyperintense lesion (arrow) next to gallbladder. D, CT scan obtained during arterial portography shows portal perfusion defect. E, Photograph of fixed specimen shows gathering necrotic foci and mixed nodular cirrhosis.

portal vein in patients with hepatic carcinoma and because of reconstruction of the liver parenchyma and reduced portal flow in patients with cirrhosis.

The cause of the lesion in our case is unknown, as the patient had no history of massive gastrointestinal hemorrhage, shock, hepatic embolization therapy, or diabetic ketoacidosis [5]. The lesion was focal, so a local circulatory disturbance or some toxic effect may have induced it.

The presence of granulation tissue around the necrosis in our case implies that the lesion is in its chronic phase, and we assume that the neovascularity and tumor stain on angiography are explained by newly formed capillary vessels in this granulation tissue. It is noteworthy that the signal intensity of the lesion was greater than that of surrounding tissue on both T1- and T2-weighted images. This pattern is common in hepatocellular carcinoma, but a necrotic hepatocellular carcinoma showing coagulative necrosis often appears hypointense relative to surrounding tissue on T2-weighted images [6], although in the relatively early stage after embolization therapy, the signal pattern may vary. The granulation tissue with numerous small vessels that is both around and within the nodule may explain the increased signal intensity on T2-weighted images, although the hyperintensity on the T1-weighted images is difficult to explain because no evidence of fat or hemorrhage was found.

Radiologists must know about ischemic necrosis associated with cirrhosis, which can resemble hepatocellular carcinoma radiologically and macroscopically. Transcatheter

arterial embolization therapy is being used increasingly for hepatocellular carcinoma, with injury of the intrahepatic microvasculature reported as a potential complication [7]. Under such circumstances, the local circulation may be disturbed in the liver, facilitating the development of an ischemic state and liver infarction. Thus, we predict that radiologists will increasingly encounter this condition. Clinical diagnosis may depend on biopsy, although differentiation between this lesion and necrotic hepatocellular carcinoma may be difficult.

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Retroperitoneal Neurilemoma: CT and MR Findings

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OBJECTIVE. Our objective was to characterize the CT and MR imaging findings of retroperitoneal neurilemmomas.

MATERIALS AND METHODS. We reviewed the CT and MR imaging findings in six women with retroperitoneal neurilemmomas.

RESULTS. Retroperitoneal neurilemmomas were round, 5–13 cm in diameter, and located in the presacral pelvic retroperitoneum in four patients and adjacent to the kidney in two patients. CT findings of the tumors were well-demarcated round masses showing prominent cystic changes and oriented in a somewhat radial fashion. Medium and heavily T2-weighted MR images showed high-intensity necrotic areas and nonnecrotic areas of various signal intensity.

CONCLUSION. CT findings of a round mass with prominent cystic degeneration, along with certain MR imaging characteristics, may be helpful in the preoperative diagnosis of retroperitoneal neurilemmomas.

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Neurilemoma is a benign neurogenic tumor arising from the sheath of peripheral nerves in the soft tissues of the head and neck, extremities, mediastinum, and retroperitoneum [1–3]. Although previous reports have described the CT characteristics of neurilemmomas in other locations as well-demarcated round masses with heterogeneous contrast enhancement [4, 5], neither the CT nor MR imaging appearance of retroperitoneal neurilemmomas has been described in previously reported cases. This study characterizes the CT and MR imaging findings in six patients with pathologically proved retroperitoneal neurilemmomas.

Materials and Methods

The medical records, radiologic studies, and pathologic reports of six patients with pathologically proved retroperitoneal neurilemoma were reviewed. CT scans were available in five patients and MR images in three. In two patients, both CT and MR imaging were performed. CT and MR images were reviewed by two of the authors.

CT scans were obtained with various scanners with a section thickness of 10 or 15 mm. Each patient received an IV bolus hand injection of 100 ml of contrast medium immediately before scanning was done.

MR imaging was performed with a 2.0-T superconducting magnet (Spectro 20,000; Goldstar, Seoul, Korea) in two patients and with a 0.5-T superconducting magnet (Supertec 5,000; Goldstar) in one patient. The section thickness was 8 mm, with an intersection gap of 2 mm. The spin-echo technique was used with imaging parameters of 500–700/30 (TR/TE) for T1-weighted images. Imaging parameters were 2000/80–85 for medium T2-weighted images and 2000/150 for heavily T2-weighted images. Contrast-enhanced T1-weighted images were also obtained in two patients after IV injection of gadopentetate dimeglumine (Magnevist; Schering, Berlin, Germany) in a dose of 0.1 mmol/kg. Signal averaging was performed twice for T1-weighted images and once for medium and heavily T2-weighted images.

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Results

All six patients were women (age range, 27–59 years old; mean, 45 years). The clinical presentation of the patients included pain or a tingling sensation in the legs in two patients and flank pain or abdominal discomfort in two. In two patients the mass was found incidentally on pelvic examination or on pelvic CT scans. The masses were located in the presacral pelvic retroperitoneum in front of the piriformis muscle in four patients and in the retroperitoneum adjacent to the kidney in two patients. The maximum diameter of the masses was 5–13 cm (mean, 9 cm).

CT scans, which were available in five patients, showed a well-defined round mass with multiple low-attenuation cystic necrotic areas in all cases (Figs. 1A and 2A). In four patients,

low-attenuation necrotic areas within the masses were well demarcated, did not extend far peripherally, and had a somewhat radial orientation. In the remaining two patients, the necrotic areas were also well demarcated but were eccentrically distributed.

MR images were available in three patients. On T1-weighted images, the masses had low to intermediate signal intensity similar to that of skeletal muscle (Fig. 1B). On T2-weighted images, the signal intensities of the necrotic areas as well as nonnecrotic areas were increased. The signal intensity of the nonnecrotic area of the tumor was similar to that of the necrotic area on medium and heavily T2-weighted images in one patient in whom hypocellular Antoni type B tissue was more prominent than hypercellular Antoni type A tissue on microscopic examination of the nonnecrotic portion

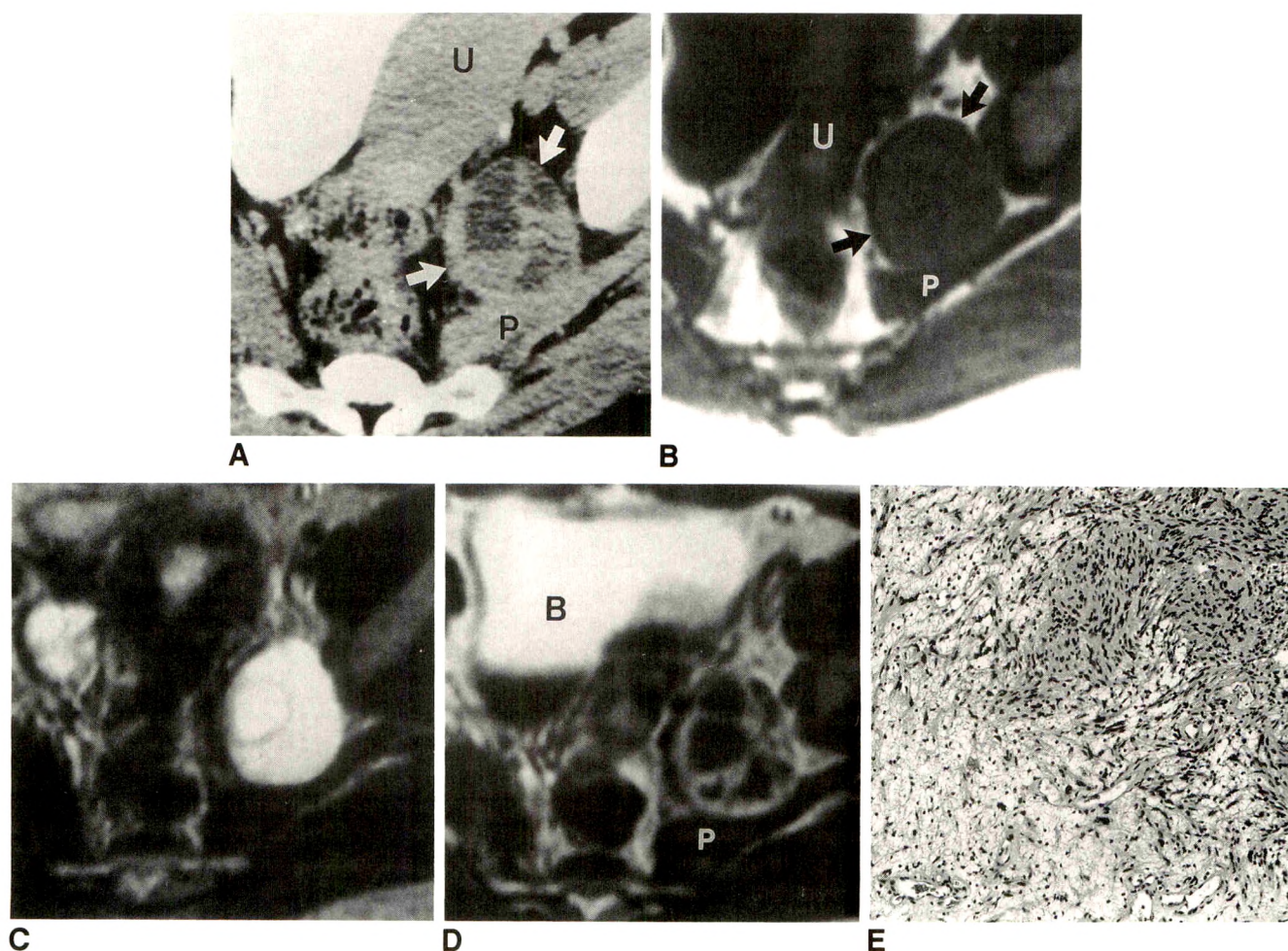


Fig. 1.—35-year-old woman with retroperitoneal neurilemoma in left presacral area in front of piriformis muscle.

A, Contrast-enhanced CT scan shows well-defined round mass (arrows) containing multiple necrotic areas of low attenuation in left pelvic retroperitoneal region in front of piriformis muscle (P). U = uterus.

B, T1-weighted MR image (700/30) shows round mass of homogeneous intermediate signal intensity (arrows) similar to that of skeletal muscles. Mass is abutting and compressing piriformis muscle (P). U = uterus.

C, T2-weighted MR image (2000/80) shows markedly increased signal intensity of mass with relatively homogeneous appearance.

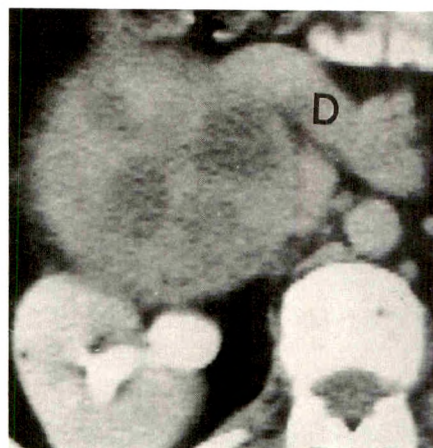
D, Contrast-enhanced T1-weighted MR image (700/30) shows mass composed of radially distributed nonenhancing necrotic areas and highly enhancing nonnecrotic portions. P = piriformis muscle, B = urinary bladder.

E, Photomicrograph of nonnecrotic portion of tumor shows two components of tumor, highly cellular Antoni type A tissue (upper right) and loose hypocellular Antoni type B tissue (lower left). Areas of Antoni type B tissue were more prominent than those of Antoni type A in this case.

Fig. 2.—48-year-old woman with retroperitoneal neurilemoma.

A, Contrast-enhanced CT scan shows a round mass anterior to right kidney containing multiple round necrotic areas. D = third portion of duodenum.

B, Cut surface of gross specimen shows multiple areas of cystic and hemorrhagic degeneration and intervening nonnecrotic portions.



A



B

(Figs. 1C and 1E). On the other hand, the signal intensity of the nonnecrotic area was lower than that of the necrotic area on medium and heavily T2-weighted images in two patients in whom Antoni type A tissue was more prominent than Antoni type B tissue. Contrast-enhanced T1-weighted images clearly showed nonenhancing necrotic areas and enhancing nonnecrotic areas (Fig. 1D).

Discussion

Neurilemoma—also known as benign schwannoma, neurinoma, and perineural fibroblastoma—is an encapsulated tumor that arises from neural sheaths of peripheral nerves [1–3]. Neurilemmomas usually occur in young to middle-aged adults, and women are affected twice as often as men [1]. The tumors may occur anywhere in the soft tissue or viscera. However, the more common locations include the soft tissue of the head and neck, flexor surface of the extremities, trunk, mediastinum, and retroperitoneum [6–8].

Neurilemmomas are fusiform, round or oval masses that are sharply circumscribed and encapsulated. They are usually less than 5 cm in diameter, but those in the mediastinum or retroperitoneum may be larger. Microscopically, neurilemmomas consist of two components: a highly ordered cellular component (Antoni type A tissue) and a loose, myxoid component (Antoni type B tissue) [1, 2].

When large, neurilemmomas are more likely to show secondary degenerative changes such as cystic degeneration and hemorrhage [2]. When neurilemmomas arise from large nerve trunks, it may be possible to clearly dissect the tumor from the nerve, since the nerve fibers do not course through the lesion but are confined to the capsule. In contrast, neurofibromas, which also are benign peripheral nerve tumors, usually cannot be dissected free from the nerves, since the nerve runs through the lesion [4, 9]. Therefore, the preoperative diagnosis of neurilemoma can be important, and MR imaging may be helpful in differentiating neurilemmomas from neurofibromas [10].

All six patients in our series were women. In four of our six cases, the tumor was located in the presacral pelvic retro-

peritoneum anterior to the piriformis muscle, suggesting the sciatic nerve as the origin of the mass [9].

The CT appearance of peripheral neurilemmomas has been described as a well-demarcated mass that is homogeneous on unenhanced scans and heterogeneous with roughly ring-shaped enhancement after contrast administration [4, 5]. These areas of heterogeneity on enhanced scans are due to cystic and hemorrhagic changes [3–11]. Well-defined round masses with multiple well-demarcated cystic necrotic areas were seen in our cases also, and we believe these findings are characteristic of retroperitoneal neurilemmomas. Neurofibromas, on the other hand, are usually homogeneous on both unenhanced and enhanced CT scans, and cystic or hemorrhagic changes are not seen [3].

MR findings of neurilemmomas—including acoustic neuromas, spinal neurinomas, and postamputation neuromas—have been described as masses of low signal intensity on T1-weighted images and of high signal intensity on T2-weighted images because of the long T1 and long T2 relaxation times of the tumor tissue [10–14]. In our three patients in whom MR imaging was performed, retroperitoneal neurilemmomas showed low to intermediate signal intensity on T1-weighted images and high signal intensity on medium and heavily T2-weighted images.

Correlation of the signal intensities on medium and heavily T2-weighted images with microscopic findings of the resected specimen suggested that the signal intensity of the peripheral nonnecrotic portion of the tumor may be related to a predominance of one of the two microscopic components of the tumor, that is, hypercellular Antoni type A tissue or hypocellular Antoni type B tissue. However, a previous article in which a comparison was made between MR signal characteristics and microscopic findings in spinal neuromas reported that it was impossible to differentiate Antoni type A from Antoni type B tissue on the basis of signal intensity features shown on T1- and T2-weighted images [11]. We think that the signal intensity of the nonnecrotic portion only rather than that of the whole mass should be compared with the microscopic findings, although this may be very difficult when spinal neuromas are small. On the basis of the three large retroperitoneal

neurilemmas in our series, we suggest that the relatively high signal intensity seen on medium and heavily T2-weighted images was caused by a predominance of hypocellular Antoni type B tissue and that the relatively low signal intensity was caused by a predominance of hypercellular Antoni type A tissue, as has been suggested previously [10].

Contrast-enhanced T1-weighted images clearly showed cystic necrotic areas and well-enhancing peripheral and intervening solid areas of the mass. The well-demarcated areas of cystic degeneration, which appeared to have a somewhat radial pattern, were prominent findings on CT and MR and were definitely seen in four of six cases. In the remaining two cases, the areas of cystic degeneration were located eccentrically.

We do not think that the pattern of cystic degeneration is diagnostic of a retroperitoneal neurilemma, since any retroperitoneal tumor with prominent cystic degeneration may have similar radiologic findings [6]. However, in addition to the prominent cystic degeneration, the characteristic location as well as MR signal intensity characteristics may lead to a correct preoperative diagnosis of retroperitoneal neurilemma, which can often be treated by simple enucleation with preservation of surrounding nerve fiber bundles.

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Case Report

Transitional Cell Carcinoma of the Renal Pelvis Associated with Cyclophosphamide Therapy

Errol Levine¹

Cyclophosphamide, an alkylating agent available since 1958, has been widely used in the treatment of various carcinomas and of B-cell malignant diseases, such as lymphoma and multiple myeloma [1]. More recently, it has been used as a therapeutic agent in collagen vascular disorders and as an immunosuppressant in bone marrow and organ transplantations [1, 2]. Well-known urologic complications associated with use of this agent include hemorrhagic cystitis, bladder fibrosis with contracture, and bladder cancer [1, 3]. However, an association between cyclophosphamide therapy and the development of high-grade and extremely aggressive renal pelvic and ureteric cancer is not generally recognized. In a review of the literature, I found only five cases of this association [4–7]. I report an additional case of transitional cell carcinoma of the renal pelvis occurring in a young patient after cyclophosphamide therapy.

Case Report

A 20-year-old man complained of gross hematuria and a dull pain in the right flank. He had no history of urinary tract signs or symptoms. Six years earlier he had undergone resection of a high-grade malignant hemangiopericytoma of his right ethmoidal air cells. After surgery, he had a 20-month course of chemotherapy that included a total IV dose of 29 g of cyclophosphamide. Clinical and radiologic follow-up showed no evidence of tumor recurrence. The patient was a nonsmoker, and he had no history of exposure to toxic chemicals. Excretory urography showed a poorly defined filling defect in the right renal pelvis. CT showed an enhancing mass in the right renal pelvis

that infiltrated the adjacent renal parenchyma and obliterated the fat in the renal sinus, consistent with a deeply invasive urothelial neoplasm (Fig. 1). No findings of regional nodal or other abdominal metastases were evident. The results of cystoscopy were normal. Ureteroscopy showed a mass in the right renal pelvis. Examination of a biopsy specimen confirmed that the mass was malignant. A right nephroureterectomy was performed.

Microscopic examination showed that the tumor was a grade 2 transitional cell carcinoma of the renal pelvis that had deeply invaded the renal parenchyma (Fig. 1), but had not metastasized to the regional lymph nodes. The right ureter showed urothelial atypia. The patient remains well 4 months after surgery.

Discussion

The therapeutic effects of cyclophosphamide depend on its activation by oxidation in the liver microsomes [7]. One of its metabolites, acrolein, is excreted in the urine and is directly toxic to the urothelium [1]. In rats, cyclophosphamide causes epithelial sloughing in the bladder with eventual regeneration progressing to epithelial hyperplasia that is sometimes papillary [4]. Since 1971, more than 40 cases of bladder cancer associated with cyclophosphamide therapy in humans have been reported [8]. Cases have occurred in patients treated with this agent for both malignant and nonmalignant diseases [1, 8]. Although most cyclophosphamide-associated bladder cancers are transitional cell carcinomas, cases of squamous cell carcinoma, undifferentiated carcinoma, adenocarcinoma, and bladder sarcoma have been reported also [1, 8]. In most cases of bladder cancer, the patients had preceding hemor-

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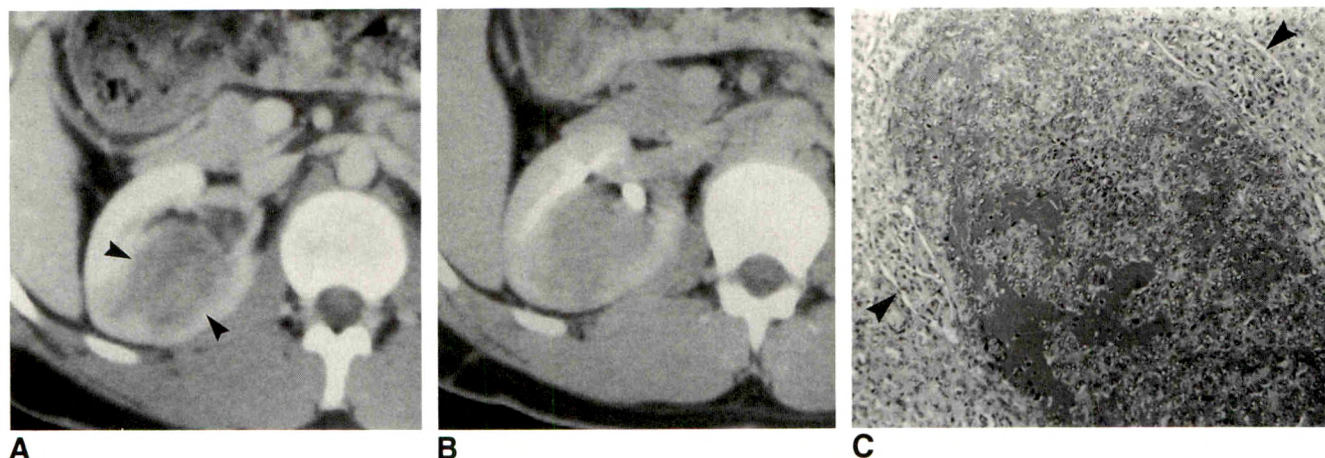


Fig. 1.—Transitional cell carcinoma of right renal pelvis.

A, Dynamic CT scan obtained immediately after bolus injection of contrast material shows enhancing mass (arrowheads; attenuation value, 71 H) in right renal pelvis. Precontrast attenuation value was 43 H. Mass obliterates fat in renal sinus. Poorly defined margin between tumor and renal parenchyma indicates parenchymal invasion.

B, CT scan obtained 5 min after A shows displacement of opacified collecting system by mass.

C, Photomicrograph of pathologic specimen shows island of tumor invading renal cortex. Note compressed glomeruli (arrowheads) at tumor margin. Tumor contains areas of hemorrhage. (H and E, original magnification $\times 100$)

rhagic cystitis and hematuria [8]. The average time from initial administration of cyclophosphamide to diagnosis of bladder cancer is about 6.5 years [8]. Thus, the risk of bladder cancer after cyclophosphamide therapy appears to be limited to relatively long-term survivors.

The findings in our patient strongly suggest a link between the development of renal pelvic carcinoma and administration of cyclophosphamide. He was 20 years old when his renal neoplasm was diagnosed; most renal pelvic carcinomas occur in patients in their sixties or older. He had no other known risk factors for a urothelial malignant neoplasm. He had received a total dose of 29 g of cyclophosphamide, and his tumor was discovered about 4 years after completion of chemotherapy. He did not have signs or symptoms of hemorrhagic cystitis during cyclophosphamide therapy.

To my knowledge, only five other cases of carcinoma of the renal pelvis or ureter associated with cyclophosphamide therapy have been reported [4–7]. Affected patients were 47–81 years old and had received cyclophosphamide for non-Hodgkin's lymphoma (three), cerebral vasculitis (one), and interstitial pneumonitis (one). The duration of cyclophosphamide therapy ranged from 16 months to 9 years (mean, 5 years) and the mean total dose administered was 179 g. Three of five patients had previous episodes of hemorrhagic cystitis. All urothelial cancers were high-grade neoplasms that resulted in death due to metastatic disease within a few months of diagnosis. The tumors included three transitional cell carcinomas, one squamous cell carcinoma, and one undifferentiated carcinoma [4–7].

Cyclophosphamide-induced urothelial malignant neoplasia may be due to a combination of a direct oncogenic effect on the urothelium and immunosuppression produced by the drug [1, 5, 7]. Although urothelial cancer develops in only a small percentage of patients treated with cyclophosphamide, the

risk of its development justifies long-term follow-up, including annual urinalysis and cytologic examination of the urine [1]. Cystoscopy and biopsy of suspicious bladder lesions should be performed in any patient in whom microscopic or gross hematuria develops or when cytologic examination of the urine suggests cancer [1, 5, 7]. However, as our case and other reported cases show, radiologists should be attuned to the possibility of upper tract urothelial cancer developing after cyclophosphamide therapy, and excretory urography also should be performed. If the urographic findings are abnormal, further evaluation with retrograde pyelography, CT, or ureteroscopy with biopsy is needed.

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Case Report

Sonographic Appearance of the Torsion Knot in Spermatic Cord Torsion

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Real-time sonography is very helpful in defining scrotal contents and has been used successfully to diagnose and evaluate many abnormalities. However, sonographic findings are not sensitive enough to differentiate spermatic cord torsion from acute epididymitis in all cases. Other techniques, such as scintigraphy [1], Doppler and color Doppler sonography [2, 3], or more recently, MR imaging [4, 5], have been proposed to improve diagnostic accuracy.

In cases of subacute testicular torsion, MR imaging has shown two specific findings: the torsion knot and the whirlpool pattern, which result from the twisting of the spermatic cord [4, 5].

We have seen two cases of testicular torsion in which sonographic findings were similar to those seen on MR images and correlated well with the anatomic changes of the twisted spermatic cord.

Case Report

A 23-year-old man had had pain in the right side of the scrotum and fever for more than 48 hr. He also noted an increasingly large mass in the right side of the scrotum. He had had no recent trauma, but recalled past episodes of transient scrotal pain. Examination of the genitalia revealed hypospadias. The right half of the scrotum was inflamed. The right testis was tender and enlarged with a mass at the upper pole.

Sonography was performed with a 3600 GE unit with a 7.5-MHz sector transducer. Sonograms showed a supratesticular mass with hypoechoic concentric layers separated by thin echogenic rims. The

central region was almost cylindrical with a central strong echo and refractive peripheral shadows (Fig. 1A). The right epididymis and testis were enlarged and hypoechogenic. At surgery, an intravaginal spermatic cord torsion with an infarcted testicle was found (Fig. 1B). Orchiectomy was performed subsequently.

Discussion

Testicular torsion results from the abnormal suspension of the testicle within the scrotum. The normal testis is surrounded by the tunica vaginalis except at the epididymis, which is in contact with the scrotal soft tissue, thus preventing torsion of the testis on the spermatic cord. Certain men have a "bell clapper" deformity in which the tunica vaginalis totally surrounds the testis, allowing torsion of the spermatic cord and compromise of the blood supply to the testis.

The major diagnostic dilemma in patients with acute or subacute scrotal pain is the differentiation of spermatic cord torsion from other abnormalities, such as torsion of testicular appendages, epididymitis, and orchitis.

Several authors have shown that sonographic findings can vary, and, in some cases, it can be difficult to distinguish between torsion and epididymitis [6, 7]. This is no longer true in institutions where the highly accurate techniques of scintigraphy, Doppler sonography, and color Doppler imaging are available. However, the problem still remains in centers where these techniques are not available or are not necessarily available 24 hr a day.

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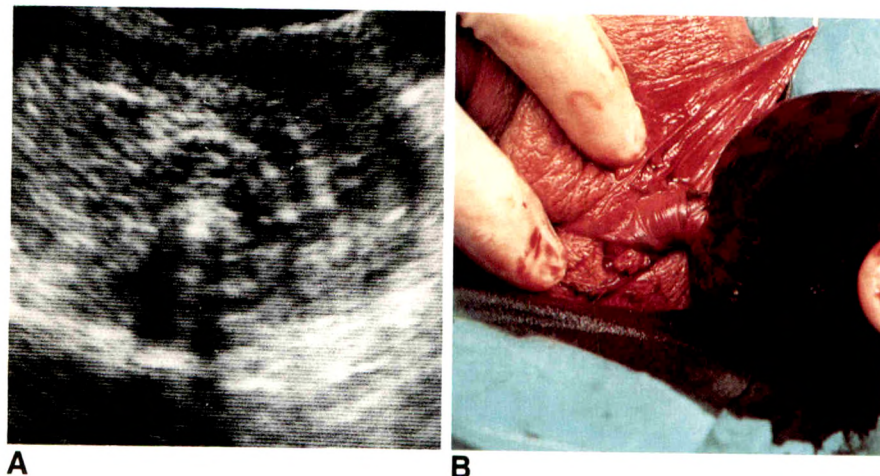


Fig. 1.—A, Transverse sonogram through right hemiscrotum shows a supratesticular mass. Concentric layers corresponding to twisted and edematous cord structures are seen along with a central region of increased echogenicity corresponding to point of twist.
B, Photograph obtained during surgery shows twisted right spermatic cord.

MR imaging shows two highly specific findings in testicular torsion: the whirlpool or twisting pattern and the torsion knot, consisting of swirls centered over a low-signal-intensity focus [5]. Additionally, the spermatic cord is often enlarged and edematous. These findings are not usually seen in epididymitis.

The findings at sonography in our two cases correlated well with such MR characteristics; the central echogenic focus was equivalent to the torsion knot seen on MR images. It is hypothesized that the low-signal-intensity knot, representing the point of the twist, resulted from the displacement of free protons from the epicenter of the twist, a concept similar to water being wrung out of a wet towel [5]. We hypothesize that changes in the impedance of the knot are the cause of the central strong echo and the refractive peripheral artifacts seen on sonograms. Furthermore, the high resolution of current sonography devices shows the anatomy of the twisted cord as a mass of concentric layers, a finding similar to the whirlpool pattern previously reported on MR images.

To our knowledge, these sonographic findings have not been described before, probably because sonographic ex-

aminations are mainly focused on changes in testicular parenchyma and the epididymis. These morphologic changes of the spermatic cord may increase the specificity of sonography in evaluating testicular abnormalities.

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MR Imaging of the Quadriceps Tendon: Normal Layered Configuration and Its Importance in Cases of Tendon Rupture

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 Stephen R. Saddemi²
 Nabil A. Ebraheim²

OBJECTIVE. The quadriceps tendon is a multilayered structure with separate layers arising from different muscle groups. We examined this layered configuration on MR images to determine if it is relevant in the evaluation of the traumatized quadriceps tendon.

MATERIALS AND METHODS. Sagittal and axial T1-weighted MR images of 52 knees with normal tendons were reviewed to determine the number and the muscle origins of these layers. Five knees with traumatized quadriceps tendons were imaged with T1 and T2 weighting to determine the relationship between the layered configuration and the injury.

RESULTS. All the normal quadriceps tendons had a laminated appearance with either four (6%), three (56%), or two (30%) layers. In 8%, the laminations were barely perceptible. The site of origin of each layer was consistent, and each favored a given muscle. The superficial layer originated from the posterior fascia of the rectus femoris muscle, and the deep layer originated from the anterior fascia of the midline vastus intermedius muscle. The middle layer(s) arose from the deep fascia separating the vastus medialis and the vastus lateralis muscles from the vastus intermedius muscle. When only two layers were present, the middle layer merged with the superficial and deep layers. In the injured tendon, complete rupture produced transection of all the layers. Incomplete ruptures were seen as focal discontinuities of individual layers; other layers remained intact.

CONCLUSION. The existence of a layered configuration of the quadriceps tendon is significant in the MR examination of partial ruptures. It can help not only in detecting and localizing injuries but also in determining appropriate treatment based on the number or thickness of injured layers.

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The quadriceps muscle is composed of four individual muscle groups. The vastus intermedius, vastus medialis, and vastus lateralis muscles arise from the proximal femoral shaft, whereas the rectus femoris muscle originates from the anterior inferior iliac spine. All four converge to insert commonly on the patella as the quadriceps tendon. On MR images, the quadriceps tendon is often seen as a multilayered structure [1]. Anatomic specimens show a similar appearance [2].

We examined normal quadriceps tendons on MR images to determine how this layered configuration may be clinically significant in the examination of the traumatized tendon.

Materials and Methods

A 1.5-T General Electric Signa scanner (Milwaukee, WI) and a GE extremity coil were used for all scans. Fifty-two normal quadriceps tendons were analyzed: 26 in a group of patients having MR examinations of the knee for conditions other than quadriceps injuries and 26 in control subjects. Of the total, 26 examinations were performed in men and 26 in women. For T1-weighted images, we used a repetition time (TR) of 400-600 msec and a typical echo

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time (TE) of 20 msec (i.e., 400–600/20 [TR/TE]). For sagittal images, the slice thickness was 3 mm with a 1.5-mm gap; for axial images, it was 5 mm with a 2.5-mm gap. A 16- or 18-cm field of view was used with a 256 × 192 matrix and two excitations.

In addition to the normal quadriceps tendons, five abnormal quadriceps tendons were examined. Four were in patients who recently had trauma and one was in a patient who had pain and weakness in the quadriceps muscle after trauma approximately 1 year earlier. Imaging parameters were the same except that T2-weighted images (2000/20,80) were obtained in addition to the T1-weighted images.

Each set of images of the 52 normal tendons was analyzed for the number of layers constituting the quadriceps tendon and each layer's main muscle of origin and convergence pattern. Average tendon thickness in the anteroposterior plane and tendon width were also recorded.

Results

All the normal quadriceps tendons had a laminated appearance. Three tendons (6%) had four layers, 29 (56%) had three layers (Fig. 1), and 16 (30%) had two layers (Fig. 2), as visualized sagittally in midline. However, no tendon had a uniform number of layers throughout. Most tendons had combinations of one, two, and three layers when viewed from side to side. The lateral aspect usually had a single thick layer, and the medial aspect usually had two or three layers. In four tendons (8%), the laminations were so faint throughout that the appearance simulated that of a single-layered structure.

In the few cases in which four discrete layers were seen, the thickness of the layers was similar. When two or three layers were seen, some tendons showed uniform thickness of all the layers and others showed considerable variability.

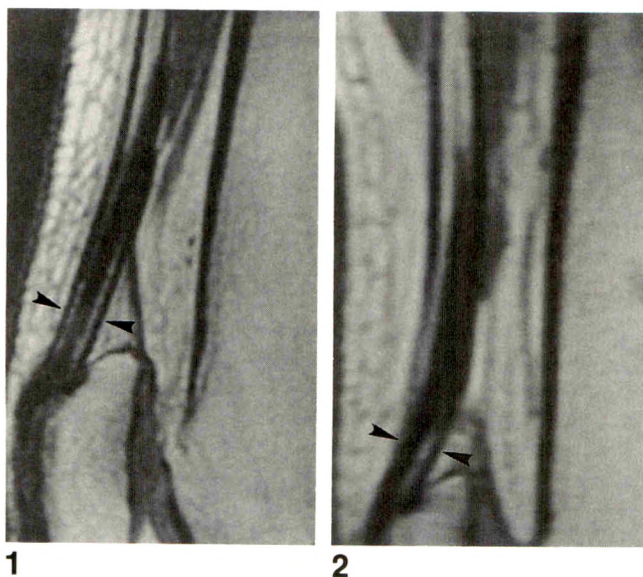


Fig. 1.—Normal quadriceps tendon with three layers. Midline sagittal T1-weighted MR image shows three distinct layers (arrowheads). Superficial layer arises from posterior rectus femoris muscle, deep layer arises from anterior midline vastus intermedius muscle, and thicker middle layer represents combined contributions from posterior fascia of vastus medialis and vastus lateralis muscles.

Fig. 2.—Normal quadriceps tendon with two layers. Midline sagittal T1-weighted MR image shows two layers (arrowheads). Superficial layer in this example is thicker than deep layer, indicating that middle layer has merged mostly with rectus femoris layer.

In several tendons, the thicknesses of the layers and the number of layers varied from side to side.

Axial images through the proximal tendon (Fig. 3) showed that the superficial layer originated from the rectus femoris muscle as thickening of the deep fascia posterior to this muscle. The deep layer originated from the vastus intermedius muscle as thickening of the deep fascia anterior to the midline of this muscle. Two middle layers originated from the posterior fascia of the vastus medialis and the vastus lateralis muscles, respectively. Portions of this fascia separate these muscles from the underlying vastus intermedius muscle. Therefore, although these layers may serve predominantly the vastus medialis and the vastus lateralis muscles, they also partly serve the vastus intermedius muscle, especially the larger component of this muscle laterally. These medial and lateral middle layers remained discrete to form a four-layered tendon, merged with each other in midline between the superficial and deep layers to form a typical three-layered tendon, or merged in various combinations with the superficial and deep layers to form tendons with variable numbers of layers and variable thicknesses of each layer. For example, when only two layers were seen on the MR image, the middle layers from the vastus medialis and the vastus lateralis muscles merged with either the superficial layer from the rectus femoris muscle or the deep layer from the vastus intermedius muscle or both (Fig. 4). The thickness of each final layer was related to the number of original layers that merged to form it.

Axial images through the distal tendon showed a greater degree of merging on the lateral aspect, which usually had only one thick layer, than on the medial aspect, which usually had two or three layers (Fig. 5). Images at this level showed that the vastus medialis and the vastus lateralis muscles were served by all of the layers. Therefore, although each layer has an origin closely related to one of the four quadriceps muscle groups, and may serve that group primarily, none of the separate layers is exclusive to a single muscle.

The average thickness ($\pm$ SD) of the quadriceps tendon in the anteroposterior plane was 8 ± 2 mm. The average width from side to side was 35 ± 7 mm.

Findings on MR images of the five abnormal quadriceps tendons were as follows: (1) complete rupture, with all the layers transected (Fig. 6); (2) partial rupture, with discontinuity of the vastus intermedius layer (Fig. 7); (3) partial rupture of the vastus lateralis muscle and tendon layer with retraction of the latter from midline (Fig. 8); (4) partial rupture, with discontinuity of the rectus femoris layer (Fig. 9); and (5) a thin but intact rectus femoris layer with focally thickened middle and deep layers suggesting previous localized trauma to the vastii tendons and subsequent chronic tendonitis (Fig. 10).

Discussion

MR imaging has become widely accepted as the method of choice for the general evaluation of tendons, particularly injured tendons [3, 4]. MR demonstration of complete rupture of the quadriceps tendon has been described [5–7], and some reference to partial ruptures has been made [1].

This study shows that the quadriceps tendon is a multilayered or laminated structure because each of the four quadriceps muscles may potentially give a separate layer to the

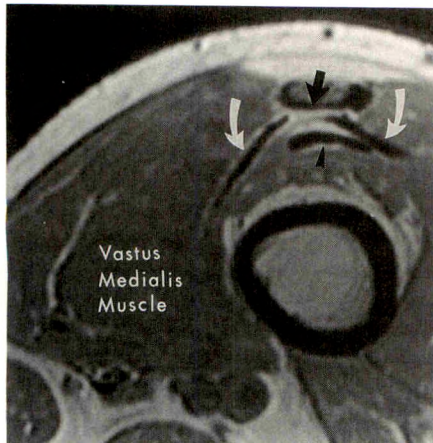


Fig. 3.—Proximal aspect of normal left quadriceps tendon with three layers. Axial T1-weighted MR image shows superficial layer originating from rectus femoris muscle (straight arrow), deep layer from vastus intermedius muscle (arrowhead), and middle layer from joining of contributing layers from vastus medialis and vastus lateralis muscles (curved arrows).

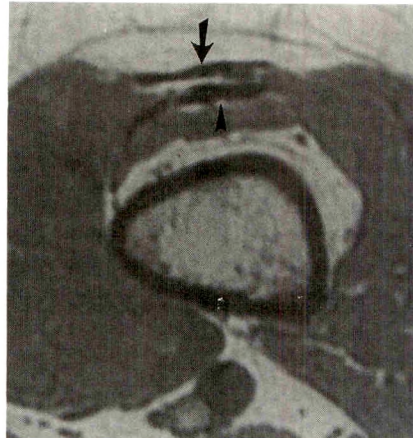


Fig. 4.—Proximal aspect of normal left quadriceps tendon with two layers. Axial T1-weighted MR image shows middle layers joining with deep (arrowhead) and superficial (arrow) layers.

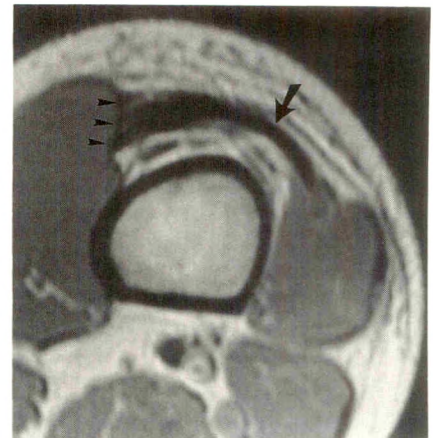


Fig. 5.—Distal aspect of normal left quadriceps tendon. Axial T1-weighted MR image shows single layer along lateral edge of tendon (arrow) and three layers toward midline and medial margin (arrowheads).

tendon (Figs. 1–4). Most tendons in this study were composed of either two (30%) or three (56%) layers. Although the tendon is a conjoint structure serving all the muscle groups combined, the most superficial layer arises from the rectus femoris muscle and the deepest layer from the vastus intermedius muscle. The vastus medialis and the vastus lateralis muscles may join with each of these layers in varying proportions (two-layered tendon) or may form an additional layer between the superficial and deep layers (three-layered tendon). The number of layers, therefore, is determined by whether the vastus medialis and the vastus lateralis layers converge with the superficial and deep layers or remain discrete. Rarely, four thin layers (6%) were seen, one from each of the quadriceps muscles. Also rare was convergence of all the layers, giving the impression of a single tendon band (8%), although some faint striation was present.

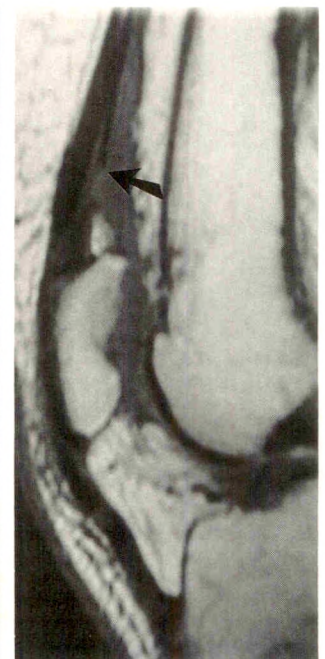
Variation occurred not only in the number of individual tendon layers but also in the thickness of each layer. Both number and thickness can be related to the relative contribution received by each final layer from the muscle groups. However, despite these variations, the overall tendon thickness was relatively constant at 8 ± 2 mm.

Each tendon typically had more layers in its midline and medial portions than in its lateral portion. Axial views show greater convergence of individual layers laterally than medially, probably because the vastus lateralis muscle does not extend as far distally as the vastus medialis muscle (Fig. 5). The transverse width of the tendon showed relatively little variability; the average was 35 ± 7 mm.

The five abnormal quadriceps tendons had a spectrum of changes that could be related to the laminated configuration of the tendon. Transection of all layers resulted in complete tendon rupture. This was the expected clinical diagnosis in one patient (Fig. 6). Even though complete rupture occasionally is a diagnostic dilemma [6], in most cases in which an obvious tendon gap exists and loss of extensor function



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Fig. 6.—Patient with complete rupture of proximal quadriceps tendon. Sagittal intermediate-weighted MR image shows three-layered quadriceps tendon has been completely transected. Proximal tendon is retracted (straight arrow), distal tendon is buckled (curved arrow), and hematoma is present in between (arrowheads). Unusually proximal location of rupture is due to underlying previous injury to thigh.

Fig. 7.—Patient with partial rupture of quadriceps tendon involving vastus intermedius layer. Sagittal T1-weighted MR image shows multilayered tendon with discontinuity of very thin deep layer (arrow). Remainder of tendon is intact. Note effusion in suprapatellar bursa.

occurs, MR serves primarily to confirm the clinical diagnosis before surgical repair. However, partial tendon injuries are more difficult to evaluate thoroughly on physical examination, so MR findings are helpful in diagnosis and in planning treat-

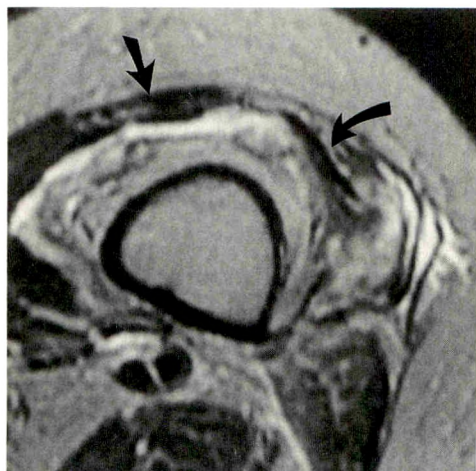


Fig. 8.—Patient with partial rupture of quadriceps muscle and tendon involving vastus lateralis muscle. Axial T2-weighted MR image shows slight retraction of vastus lateralis tendon layer (curved arrow) from main tendon (straight arrow), with hemorrhage and edema in adjacent muscle and soft tissues. Remainder of tendon is intact. Compare vastus lateralis layer with normal appearance in Fig. 5.

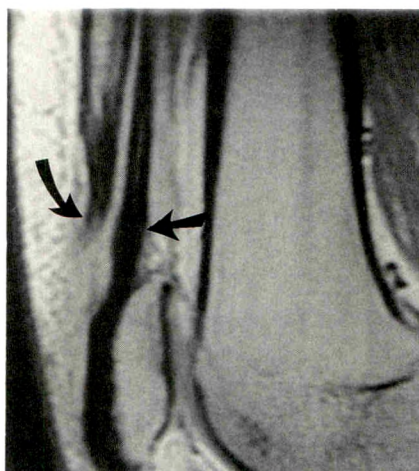


Fig. 9.—Patient with partial rupture of quadriceps tendon involving rectus femoris layer. Sagittal T1-weighted MR image shows two-layered tendon with rupture of superficial layer from rectus femoris muscle (curved arrow). Deep layer, serving remaining quadriceps muscles, remains intact (straight arrow).

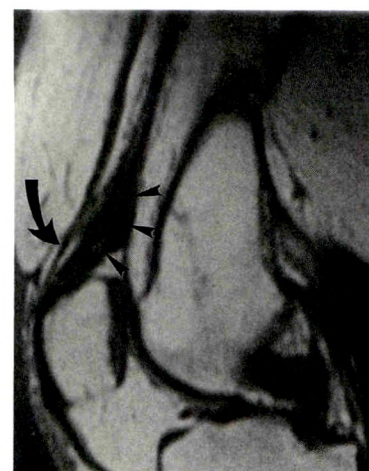


Fig. 10.—Patient with chronic tendonitis of middle and deep layers associated with previous injury to vastus intermedius, vastus medialis, and vastus lateralis muscles. Sagittal T1-weighted MR image shows thin but normal appearance of superficial layer from rectus femoris muscle (arrow). Middle and deep layers are thickened (arrowheads).

ment. In our patients, partial ruptures were seen as focal discontinuities of one or more of the layers, with the other layers still intact. Two patients were thought to have quadriceps injury because of their history and the presence of focal pain and tenderness. No palpable tendon defects were present, and extensor function, although mildly uncomfortable, was intact in both patients. MR images showed partial tendon ruptures, localized the injuries to specific tendon layers (vastus intermedius and vastus lateralis muscles, respectively), and showed the relatively mild degree of injury in each patient (Figs. 7 and 8). Another patient had sudden onset of suprapatellar pain after jumping. No tendon defect was palpable, full leg extension was achieved with minimal discomfort, and minor injury was suspected clinically. MR showed rupture of the superficial quadriceps tendon layer, with a prominent intact deep layer (Fig. 9). The defect was not palpable because of retraction of the ruptured rectus femoris layer and the thickness of the intact deep vastus intermedius, vastus medialis, and vastus lateralis layers. The injury was repaired surgically. In none of our acutely injured patients were there focal areas of attenuation or high T2 signal within one of the individual layers, although this would be more likely to occur in a thick layer formed by the convergence of two or three layers. In the fifth patient with an abnormal quadriceps tendon, the clinical impression was "quadriceps insufficiency" after injury several months before, at which time no medical evaluation had been sought. MR images showed a thin, intact superficial tendon layer from the rectus femoris muscle and focally thickened middle and deep layers from the vastus intermedius, vastus medialis, and vastus lateralis muscles (Fig. 10). Most likely this patient had a partial rupture of these deep components during the original injury, and chronic tendonitis developed subsequently.

In summary, the quadriceps tendon is seen as a laminated structure on MR images with layers arising from separate muscle groups. Recognition of the various appearances is important, particularly in evaluations of incompletely ruptured tendons, because such injuries may be produced by discontinuities of individual layers. MR imaging can be used for the specific diagnosis of partial rupture and for accurate assessment of the extent of injury, which are important in planning effective treatment.

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Case Report

Mucormycosis Osteomyelitis Causing Avascular Necrosis of the Cuboid Bone: MR Imaging Findings

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Mucormycosis is an uncommon but highly invasive fungal infection known to affect immunocompromised patients, especially those with diabetes mellitus, hematologic malignant diseases, and renal failure. The most usual form is rhinocerebral, although it can have pulmonary, intestinal, disseminated, or cutaneous manifestations [1]. We report a case of a renal transplantation patient who had pain and swelling in the foot and was found to have mucormycosis osteomyelitis causing avascular necrosis of the cuboid bone. To our knowledge, this is the first description of mucormycosis causing osteomyelitis and avascular necrosis.

Case Report

A 63-year-old man with polycystic kidney disease was treated with continuous ambulatory peritoneal dialysis for 8 months before receiving his first cadaveric renal transplant in June 1991. The onset of graft function was delayed for 6 weeks because of acute tubular necrosis and mild rejection. Initial immunosuppression was with prednisolone, azathioprine, and antilymphocyte globulin, which was given for 10 days. Cyclosporin was started after the course of antilymphocyte globulin had been completed. No further episodes of rejection occurred, and his plasma creatinine level fell to about 200 $\mu\text{mol/l}$. He was never neutropenic.

Three months after transplantation, he was admitted for treatment of bowel perforation due to cytomegalovirus infection and *Pseudomonas* sepsis. While he was hospitalized, pain, swelling, and erythema developed in the lateral aspect of his right foot. A soft-tissue

abscess was drained from this site, yielding a culture of *Pseudomonas*. We noted subsequent development of two fistulous tracks from the cuboid bone to the skin, which did not communicate with each other, as well as two other superficial abscesses on the dorsum of the foot remote from the cuboid bone, and a further abscess immediately above the lateral malleolus. The last three lesions showed no evidence of surrounding inflammation and raised a clinical suspicion of fungal infection, although no fungal growth was obtained on culture.

Findings on plain radiographs of the foot were normal apart from extensive soft-tissue thickening and a lucency corresponding to a track from the cuboid bone to the skin. No bone abnormality was discernible (Fig. 1A). The patient was referred for scintigraphy and MR imaging to exclude osteomyelitis. The radionuclide bone scan, using ^{99m}Tc-methylene diphosphonate (MDP), showed intense radionuclide uptake surrounding the cuboid bone on equilibrium and static phases, with a large central area devoid of radionuclide uptake (Fig. 1B). MR images showed low signal on the T1-weighted image (500/20 [TR/TE]) with a surrounding rim of lower intensity, affecting only the cuboid bone (Fig. 1C). No enhancement occurred after administration of gadopentetate dimeglumine (0.1 mmol/kg) except in the hyperemic soft tissues (Fig. 1D). Signal intensity was high on the short T1 inversion recovery (STIR) image (1800/30/150 [TR/TE/TI]) both in the affected bone and in the surrounding soft tissues (Fig. 1E).

Surgical exploration and biopsy of the cuboid bone were undertaken. The subcutaneous tissues were infarcted with pus formation. *Pseudomonas* was cultured from the soft tissues. Results of the bone biopsy showed extensive necrosis of trabeculae and the marrow

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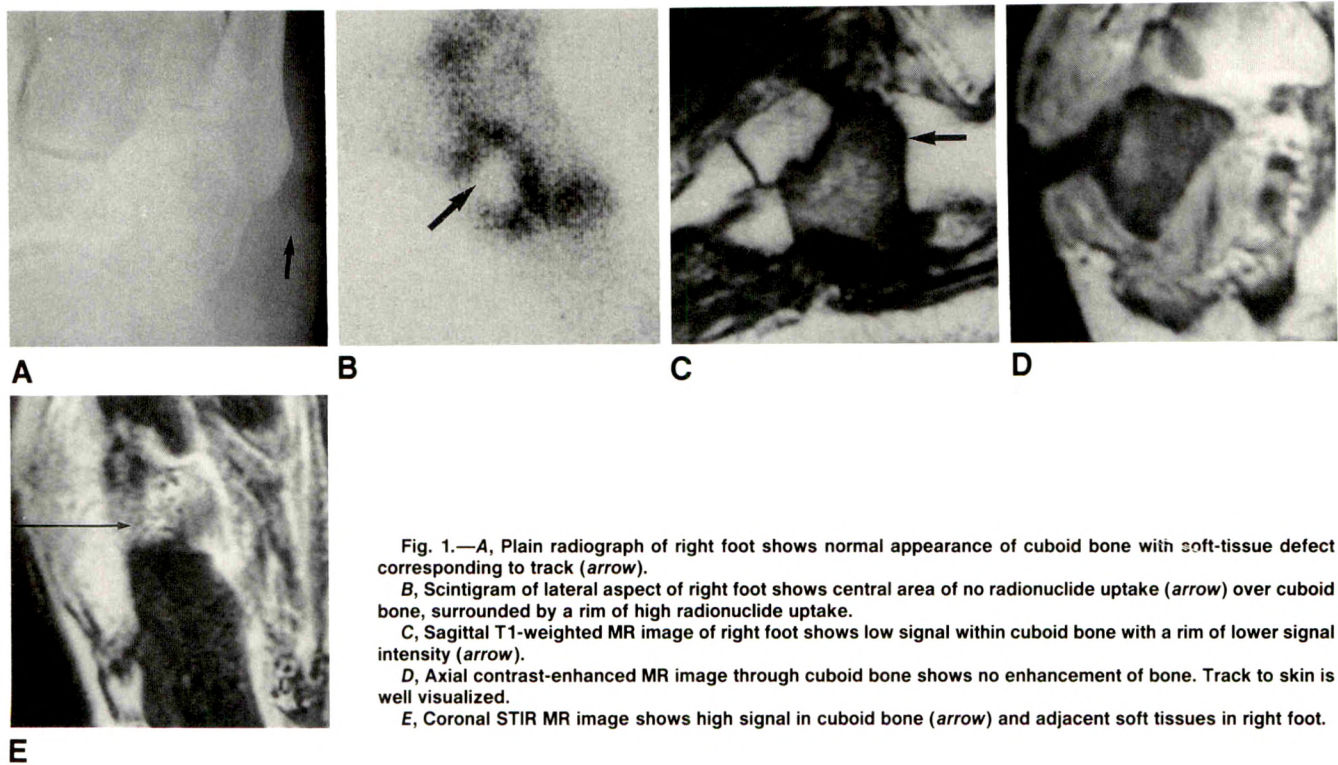


Fig. 1.—A, Plain radiograph of right foot shows normal appearance of cuboid bone with soft-tissue defect corresponding to track (arrow).
 B, Scintigram of lateral aspect of right foot shows central area of no radionuclide uptake (arrow) over cuboid bone, surrounded by a rim of high radionuclide uptake.
 C, Sagittal T1-weighted MR image of right foot shows low signal within cuboid bone with a rim of lower signal intensity (arrow).
 D, Axial contrast-enhanced MR image through cuboid bone shows no enhancement of bone. Track to skin is well visualized.
 E, Coronal STIR MR image shows high signal in cuboid bone (arrow) and adjacent soft tissues in right foot.

space with a predominantly acute inflammatory cellular infiltrate and numerous broad aseptate fungal hyphae having the typical morphologic appearance of mucormycosis. A zygomycete fungus, *Rhizopus rhizopodoformis*, was subsequently grown on culture. The cuboid bone was excised, the wound was debrided, and IV amphotericin was administered for 4 weeks. The patient had a good recovery and was discharged well with a functioning renal transplant.

Discussion

Mucormycosis is a fungus of the class Zygomycetes, family Mucoraceae, and usually of the genera *Rhizopus*, *Rhizomucor*, or *Absidia*. These fungi are ubiquitous in the environment, and, it has been said, in hospital wards, but environmental cultures taken regularly throughout a 10-year period in another institution [2] have seldom yielded the organism found in this case, *Rhizopus rhizopodoformis*. Patients particularly at risk for infection with this agent are those who are diabetic or immunocompromised, whether from high doses of steroids, hyperglycemia, antirejection therapy (as in transplantation patients), or neutropenia [3]. The infection has been reported in patients undergoing hemodialysis who were receiving desferrioxamine for iron overload [4]. Transmission is usually by inhalation or by direct invasion of the bowel in malnutrition. Skin and subcutaneous tissues subjected to thermal burns and nosocomial infections have become infected after application of contaminated dressings [2, 5], but screening of dressing packs in this case did not show any evidence of mucormycosis infection. It is of particular interest that another patient with renal failure who had extensive rhinocerebral mucormycosis, diagnosed 3 months previously,

was an inpatient on the same ward as our patient. It is, however, surprising that, if infection had been transmitted by inhalation, no rhinocerebral disease or evidence of disseminated mucormycosis infection occurred other than in the foot of our patient. It remains possible that secondary infection occurred through the initial abscess drainage site from airborne spores, but the fungus was never cultured from this site.

This fungus causes invasion of blood vessels, leading to tissue ischemia and hemorrhagic infarction depending on arterial or venous involvement, and an intense inflammatory response. Isolated cuboid bone involvement with total avascular necrosis suggests loss of periosteal and nutrient arterial supply or diffuse central venous occlusion. As it spreads through perivascular spaces, bone destruction is an uncommon and late finding in rhinocerebral disease even when the surrounding tissues are extensively involved. These features are reflected in the radiographic, scintigraphic, and MR findings.

This patient was referred for scintigraphy and MR imaging because the clinical presentation was of cellulitis, and underlying osteomyelitis was suspected. In osteomyelitis, bone scintigraphy would be expected to show a focal increase in radionuclide activity in the affected bone. The scintigraphic appearance in this case was not that of osteomyelitis, but that of avascular necrosis. The normal or reactive bone adjacent to the ischemic region showed increased radionuclide uptake in contrast to the lack of uptake in the central avascular portion of bone. This is compatible with the normal radiographic findings in early avascular necrosis as the mineral content of the bone is preserved while the cellular elements

in the marrow are affected by vascular occlusion [6], although with such marked scintigraphic findings, it is surprising that no evidence of osteoporosis was seen.

MR imaging is said to be more sensitive and specific than ^{99m}Tc-MDP bone scintigraphy [7] in distinguishing between soft-tissue cellulitis, abscess, osteomyelitis, and avascular necrosis because of its increased spatial resolution. Low signal on the T1-weighted image affected only the cuboid bone, suggesting a decrease in marrow fat and an increase in water content, with no enhancement after administration of gadopentetate dimeglumine except in the hyperemic soft tissues. The high signal intensity on the STIR image both in the affected bone and in the soft tissues reflects a high water content, as occurs with hyperemia, edema, or inflammation, and would be compatible with osteomyelitis and noninfectious inflammatory conditions as well as early avascular necrosis [7, 8]. However, a rim of low signal intensity also was present around the cuboid bone on the T1-weighted image, which is consistent with class C avascular necrosis as described by Mitchell et al. [8] and does not occur in osteomyelitis unless it is long-standing. The different patterns described reflect the evolution of osteonecrosis, of which osteomyelitis can be the cause, and depend on the signal changes due to the amount of marrow fat, blood, water, and fibrosis present; other than with class C avascular necrosis, osteomyelitis is usually easily distinguished from avascular necrosis.

Mucormycosis has previously been associated with a high mortality rate. In this case, the scintigraphic and MR imaging studies were critical in the diagnosis of avascular necrosis. Owing to the rapid diagnosis, appropriate surgery and therapy could be offered to our patient. Nonetheless, the excellent and rapid response to treatment in this case is unusual in this disease.

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Rapid Growth of Femoral Herniation Pit

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Herniation pit of the femoral neck is a common, benign entity that was first formally characterized by Pitt et al. in 1982 [1]. The lesion is seen as a small rounded radiolucency, with a thin sclerotic margin, situated on the anterior surface of the femoral neck. In their original paper, Pitt et al. described two cases in which herniation pits increased in size, one during a 6-year period in a ballerina and the other during a 9-year period in an avid jogger. However, to our knowledge, no reports of more rapid growth of a herniation pit have been presented since that time.

We present a case in which the linear dimensions of a pathologically proved herniation pit more than doubled in fewer than 14 months. In order to avoid misdiagnosis, it is important to recognize that such rapid growth of this benign lesion is possible.

Case Report

A 55-year-old woman who had had pain in the left hip for several months was referred to the Section of Orthopaedic Surgery for evaluation. The clinical diagnosis at that time was left-sided ischial bursitis, and findings on the initial radiographs and all subsequent radiologic studies of the left hip were normal. However, incidentally noted on the initial radiographs of the pelvis and hips was a well-defined, 9 × 10 mm lucent lesion, with sclerotic margins, in the right femoral neck (Fig. 1A).

The patient had not had any signs or symptoms related to the right hip. At this time, the diagnosis of a probable herniation pit was made, but osteoid osteoma was considered as a less likely possibility. Two months after the initial plain films, a triple-phase bone scan was obtained (Fig. 1D). This showed normal flow and blood-pool phases, but delayed images revealed a focal region of abnormally increased uptake of radionuclide within the right femoral neck, corresponding to the lesion seen on radiographs.

The lesion was thought to be benign, most likely a herniation pit, but it was decided to do follow-up studies. A radiograph obtained 8 months after initial presentation showed that the lesion had increased

in size to 17 × 14 mm and had become slightly lobulated (Fig. 1B). The lesion was followed up for a further 6 months, and another radiograph was obtained. At that time, 14 months after initial presentation, the lesion had increased in size to 23 × 16 mm; thin sclerotic margins were still present, but the contour was more lobulated (Fig. 1C).

Throughout this time the patient had remained asymptomatic relative to the right hip. The lesion was still thought to be consistent with a herniation pit, but because of the rapid increase in size, CT scans and MR images were obtained (Figs. 1E–1H). CT scans showed a well-defined lesion of soft-tissue attenuation, with sclerotic margins, on the anterior surface of the femoral neck. The lesion had a cortical roof and a focal perforation 1 mm in diameter. MR images showed a lesion that had uniformly low signal on T1-weighted images and no significant enhancement after administration of contrast material. On T2-weighted images, the lesion was of uniformly high signal intensity.

At this time, the imaging characteristics were considered typical for an enlarging, but otherwise unremarkable, herniation pit. Despite the benign prognosis, the patient decided she wanted a biopsy of the lesion; this was done 14 months after her initial presentation.

The lesion was resected by using a CORB biopsy needle (Zimmer Inc., Warsaw, IN) and a pituitary rongeur. Macroscopically, the lesion consisted of "slimy gray-white tissue." Histologic examination showed a dense fibrous connective tissue with poorly defined foci, which were of looser texture and myxoid appearance. Fragments of cartilage, bone, and fibrinous material also were present.

Discussion

A herniation pit of the femoral neck arises in relation to the "reaction area," an area of sclerotic bone, covered by collagenous tissue and neocartilage, present in the anterolateral region of the upper femoral neck in most adults [2]. Ingrowth of these fibrous and cartilaginous elements occurs through a perforation in the cortex; these tissues then expand in a subcortical location to form the radiographically identifiable

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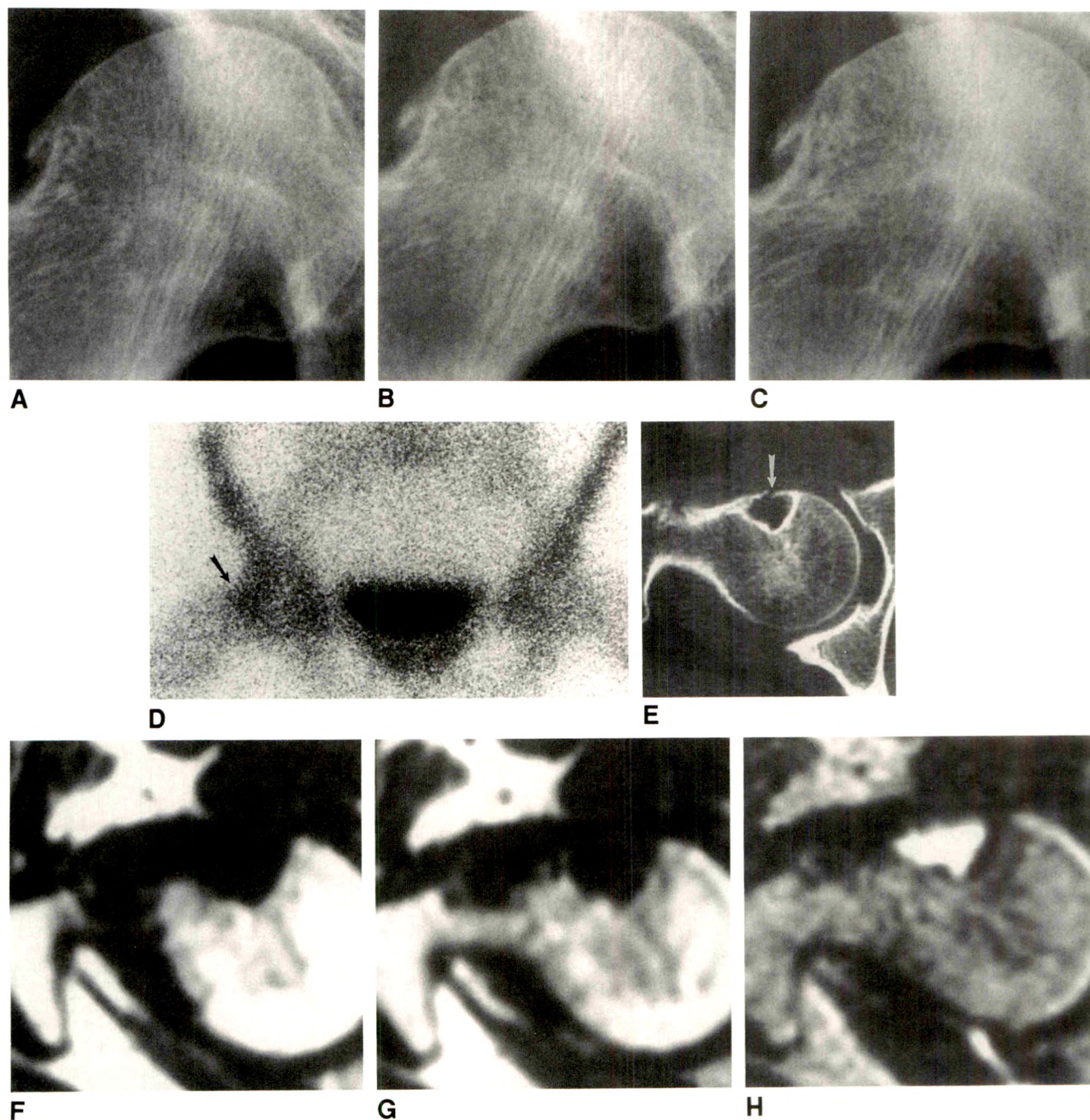


Fig. 1.—Herniation pit of femoral neck in a 55-year-old woman.

A–C, Radiographs show progressive enlargement of a right femoral herniation pit from time of initial presentation (A), to 8 months after A (B), to 6 months after B (C).

D, Delayed image from a bone scan obtained 2 months after A shows increased uptake of radionuclide in area associated with lesion (arrow), best seen on this anterior frog-leg view.

E, CT scan, 14 months after A, shows a well-defined subcortical lytic lesion, with sclerotic margins and a cortical perforation (arrow), in right hip.

F–H, MR images of right hip obtained 14 months after A. T1-weighted, 500/11 (1.5 T) images (F and G) show a lesion of low signal intensity, with a thin dark rim, that does not enhance (G) after administration of contrast material. T2-weighted, 2500/80, image (H) shows a lesion with a high signal and a dark rim.

lesion. The presumed “driving force” behind this herniation of fibrous tissue and cartilage is the pressure and abrasive effect of the overlying hip capsule and anterior muscles (rectus femoris and iliopsoas).

The lesion described in this report had characteristics typical of a herniation pit, as described by Pitt et al. [1]. On plain

films, the lesion was well defined and rounded, but subsequently became lobulated. The CT findings were characteristic [1], namely, a well-defined subcortical lytic lesion, with a visible cortical perforation.

A previous report [3] on the MR appearances of these lesions showed the herniation pit as uniformly dark on T1-

weighted images. On T2-weighted images, six of seven lesions were bright, consistent with the presence of fluid. In our case, signal of the lesion on T2-weighted images was high enough to suggest the presence of a fluid component.

The herniation pit was initially described as showing no increased uptake of radionuclide on bone scintigrams [1]; subsequently, increased activity has been described [4]. Increased uptake presumably is related to active bone remodeling and repair, and so might be expected to be more prominent in the more rapidly expanding lesions. This was true in our case: increased uptake of radionuclide on delayed images is consistent with increased bone remodeling associated with the expanding lesion, whereas normal flow and blood-pool phases are consistent with a relatively avascular lesion.

Both reported cases of enlarging herniation pits [1] were in patients with a history of athletic physical activity; one was a jogger, the other a ballerina. Our patient had a similar history: she had a long history of dancing, including ballet, and, in the period over which the growth of the lesion was recorded, she was walking 4 miles a day. It is plausible that the development and progression of these lesions are related in some way to physical activity. Habitual hyperextension of the hip has been postulated as a cause [1], and this seems plausible, because in extension, pressure is applied to the reaction area by the

tightened capsule and overlying muscles. Perhaps herniation pits tend to develop in hips subjected to repeated hyperextension; herniation of the soft tissues may be likely because of existing or developing perforations in the cortex of the reaction area.

Regardless of the exact mechanism of their production, the common, but erroneous, impression is that these lesions are uniformly stable. Our case shows that these lesions can grow quite rapidly. The linear dimensions of the lesion in our case doubled in a little less than 14 months, reflecting approximately an eightfold increase in volume. The potential for such rapid growth in these lesions must be recognized in order to avoid confusing this lesion with a neoplasm or a chronic low-grade infection.

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Relapsing-Remitting Multiple Sclerosis: Sequential Enhanced MR Imaging vs Clinical Findings in Determining Disease Activity

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OBJECTIVE. Sequential MR imaging frequently shows disease activity (clinically silent new brain lesions) in subgroups of patients with multiple sclerosis and therefore is valuable in monitoring the effects of treatment. Monitoring of disease activity in patients being treated for relapsing-remitting multiple sclerosis will increase in importance as new and safe therapies are developed. We studied sequential enhanced MR images of patients with early relapsing-remitting multiple sclerosis to define the MR features that indicate disease activity in this subgroup of patients and to compare MR imaging and clinical findings for this purpose.

SUBJECTS AND METHODS. Seven patients with relapsing-remitting definite multiple sclerosis were examined monthly for 4–12 months. For each image, a standard repositioning protocol consisting of three images was used to ensure reproducibility of axial (double oblique) image planes, planned according to internal landmarks. A total of 58 unenhanced T2-weighted and enhanced T1-weighted MR images were obtained.

RESULTS. MR images showed new enhancing lesions in six of the seven patients. On 25 (43%) of the 58 enhanced T1-weighted MR images, a total of 50 new enhancing lesions were observed, and on one image a reenhancing lesion was seen. The unenhanced T2-weighted images showed corresponding abnormalities for 92% of the new enhancing lesions. At follow-up, most lesions (86%) were enhanced on only one occasion; 4% were enhanced on more than two consecutive monthly MR examinations. Forty-nine percent of the lesions seen on T2-weighted images "disappeared" (beyond the resolution of the imaging system) after a mean follow-up of 3.5 months, especially lesions that were initially smaller than 5 mm. During the study, only five clinical relapses occurred in three patients (all at times when MR images showed contrast-enhancing lesions), and fixed disability did not increase. On 21 additional occasions, MR images showed new enhancing or reenhancing lesions in patients who were clinically stable at the time (4.2 times more clinically silent disease activity).

CONCLUSION. Our results suggest that contrast-enhanced MR imaging is more sensitive than clinical monitoring for detecting new disease activity in patients with relapsing-remitting multiple sclerosis and that MR imaging might be useful in the evaluation of therapeutic regimens.

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MR imaging of the brain frequently shows new lesions in patients with multiple sclerosis (MS) who do not have accompanying clinical signs and symptoms [1–3]. MR imaging thus seems to be a sensitive marker for disease activity in MS, which makes the technique potentially useful for monitoring disease activity (e.g., in pilot studies of putative therapeutic regimens). It has been suggested that the most effective MR imaging parameter for assessment of disease activity in MS is contrast enhancement with gadopentetate dimeglumine [4–7]. Contrast enhancement is correlated with disease activity in MS [8–10] and in experimental allergic encephalitis, a disease that resembles MS [11].

Little is known about the value of using contrast-enhanced MR imaging to assess disease activity in patients with MS. Such information is important for estimating

the number of patients needed to show a certain treatment effect of a given drug. Disease activity shown on MR appears to vary widely with respect to different clinical courses of the disease. MR shows new lesions far more frequently in patients with secondary progressive disease than in patients with primary progressive disease [5]. Patients with early relapsing-remitting disease have more lesions than do patients with benign disease [3], and the number of lesions is similar to the number seen in patients with secondary progressive disease. Within well-defined populations, however, variations in the MR features of disease activity in individual patients and within a group of patients are substantial.

Monitoring disease activity in a group of patients with relapsing-remitting MS will become increasingly important as new and safe therapies are developed to prevent new disease activity [12]. So far, only two sequential MR studies [6, 7] of relapsing-remitting MS that used contrast-enhancement have been reported. We sequentially examined seven patients with early relapsing-remitting MS to determine the value of contrast-enhanced MR images in assessing disease activity in this subgroup of patients and to compare MR imaging and clinical findings for this purpose.

Subjects and Methods

Seven patients who had relapsing-remitting definite MS according to current diagnostic criteria [13] were prospectively examined at monthly intervals for 4–12 months. The patients were examined clinically and were imaged by using a standard MR imaging protocol, including gadopentetate-dimeglumine enhancement. None of the patients was treated with corticosteroids or other immunosuppressants in the 6 months before or during the study period, as steroid medication suppresses contrast enhancement [8].

The mean age of the patients was 24 years (range, 19–36 years), and the mean duration of disease was 2.7 years (range, 0.6–5.0 years). The median clinical disability score on entry, assessed by means of the commonly used Expanded Disability Status Scale [14], was 1.5 (range, 1.0–2.0). All patients had oligoclonal bands in their

CSF on isoelectric focusing, indicating selective production of immunoglobulin G antibodies. The initial presenting signs or symptoms had been optic neuritis in three patients, sensory symptoms in three, and internuclear ophthalmoplegia in one. A relapse was defined as any clinical deterioration lasting more than 24 hr that was not related to a concurrent illness.

One patient stopped participating in the study for personal reasons after four imaging sessions. During the study, three patients had a total of five clinical relapses. These relapses led to a change in the Expanded Disability Status Scale score of 1.0 or more in three relapses. All patients recovered spontaneously. At the last imaging examination, one patient had very mild sensory symptoms that progressed and led to treatment with methylprednisolone 1 month later. The Expanded Disability Status Scale scores at the end of the study were identical to the entry scores for all patients.

MR imaging was performed with a 0.6-T machine (Technicare, Solon, OH) with a standard head coil. The same imaging protocol was used throughout the study. Identical slice positioning was achieved by means of unenhanced images in three consecutive planes (transverse, oblique coronal, and oblique sagittal), thereby correcting for differences in the patient's position according to internal landmarks (Fig. 1). From the midsagittal image, double oblique two-dimensional axial series were planned. T2-weighted spin-echo images were obtained with 2755/60,120(reduced bandwidth)/2 (TR/TE/excitations). Nineteen slices with an in-plane resolution of 1.0×1.3 mm and a slice thickness of 5 mm were obtained with a gap of 1.25 mm, resulting in a Z range of 11.75 cm. The Z center was aligned with the caudal border of the splenium of the corpus callosum (Fig. 1C).

Gadopentetate dimeglumine (Magnevist, Schering AG, Berlin, Germany) was administered IV as a bolus in a dose of 0.2 mmol/kg (recommended dose in Europe, 0.1–0.2 mmol/kg); the patient remained in the same position in the head coil as used for unenhanced imaging. A postinjection flush of 10 ml of normal saline was given. T1-weighted spin-echo images (two series of nine slices) were then obtained with 400/28(normal bandwidth)/4, in exactly the same way as the unenhanced slices were obtained (identical spatial resolution) and starting 5–10 min after contrast injection. The total examination time was 50 min.

The MR images were analyzed by two neuroradiologists in conference. Slice positioning was evaluated for each follow-up image and graded as good, moderate, or poor. Repositioning errors can result

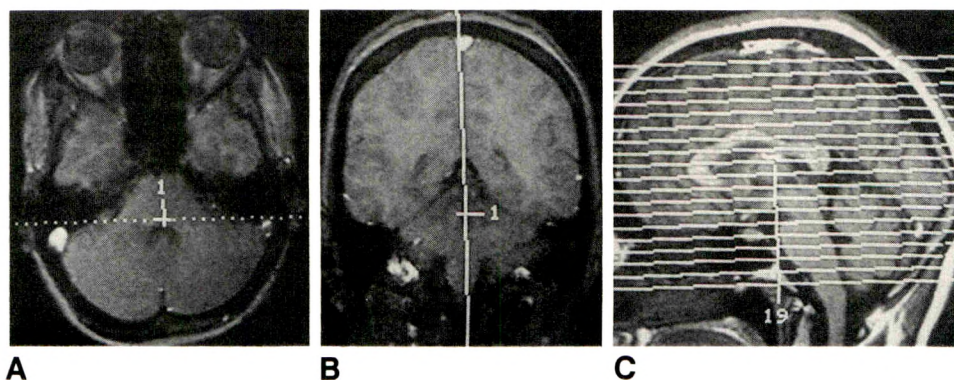


Fig. 1.—Protocol for achieving identical slice positioning for sequential axial MR images. Patient assumes a comfortable position in magnet bore. Three consecutive pilot images are used to correct for rotations along three orthogonal axes.

A, First, a transverse unenhanced MR image is obtained, from which angle of (oblique) coronal image is planned (perpendicular to midline).

B, Coronal MR image is then used to plan (oblique) sagittal image, along cerebral falx.

C, Resulting sagittal MR image, which is the logical midsagittal image, is then used to plan (double oblique) axial slices, angulated parallel to line connecting caudal border of pituitary gland and fastigium of fourth ventricle; Z center is aligned with splenium of corpus callosum. Essentially, this repositioning protocol uses only internal landmarks of brain, without any inconvenience for patient.

from either inaccuracy in anterior/posterior or left/right angulation or inaccuracy in Z offset. Repositioning was graded as good when less than half a slice of inaccuracy occurred in any part of an image, as moderate when more than half a slice but less than a whole slice of difference occurred, and as poor if differences of more than a slice occurred. An area of markedly increased signal intensity on the contrast-enhanced T1-weighted images, not related to a physiologically enhancing structure [15, 16], with a diameter of 3 mm was considered a contrast-enhancing lesion. Lesions were classified as directly periventricular (adjacent to the ventricular system), deep white matter, gray matter, junction of gray and white matter, or infratentorial. They also were classified as smaller or larger than 5 mm. On the initial T2-weighted MR images, a total lesion score was assigned by using a semiquantitative scoring system [5]. The T2-weighted images also were evaluated as to whether enhancing lesions were shown and whether the lesions changed in appearance at follow-up. Therefore, abnormalities on T2-weighted images were classified as clearly visible, poorly visible, or only recognizable because of previous knowledge of the contrast-enhanced T1-weighted images ("retrospective"). In order to exclude artificial changes attributable to repositioning errors, "disappearance" of lesions was defined as a lesion not being visible on two consecutive MR examinations.

Results

MR Imaging

A total of 58 MR images were obtained. Slice repositioning was graded as good in 39 (76%) of 51 follow-up images, moderate in 11 (22%), and poor in one (2%). In five patients, the repositioning was good in more than 75% of the images; in two patients, however, repositioning was good in less than 50% of the images.

Table 1 shows the MR imaging results. For the initial T2-weighted images, the mean total lesion score was 63.5 (range, 11–129). Six of seven patients had one or more new enhancing lesions during the study. The proportion of images per patient that showed enhancement varied from 0% to 80% (mean $\pm$ SD, $42 \pm 31\%$). Fifty new contrast-enhancing lesions were seen on 25 (43%) of the 58 images. The Pearson correlation coefficient between the initial lesion score and the mean number of enhancing lesions was 0.52 ($p = .23$), and between the initial number of lesions and the proportion of images showing enhancement it was 0.61 ($p = .14$).

Figures 2 and 3 show sequential images at two different levels in one patient. One contrast-enhancing lesion was first seen on the last set of images, after which no follow-up images were available. Most other lesions (42/49, 86%) were enhanced on only one occasion. In one patient, a total of seven lesions were still enhancing on images obtained at the first follow-up examination, two (4%) of which were still enhancing on images obtained at the second follow-up examination. In another patient, one lesion was seen to reenhance on images obtained at a second follow-up examination. This means that the total number of enhanced lesions observed during this study was 60. Thus, the mean number of enhancing lesions seen after administration of contrast material was 2.3. In two cases, new enhancing lesions were actually reactivated preexisting lesions, and in two other cases, ring en-

TABLE 1: Number of New Contrast-Enhancing Lesions on Monthly T1-Weighted MR Images of the Brain in Patients with Relapsing-Remitting Multiple Sclerosis

MR Finding	Case No.						
	1	2	3	4	5	6	7
Lesion Score on Unenhanced Image	79	11	97	129	27	50	50
No. of New Contrast-Enhancing Lesions by Month							
1	0	0	5	0	2	0	1
2	0	1	10 (13) ^a	3	1 ^a	0	0
3	1 ^a	0	2 (6)	2	1	0	0
4	0	0	2 (3)	2	0	0	1
5	–	0	1 (2)	1	3	0	0
6	–	0	2	1	1	0	0
7	–	0	2 ^a	1	0	0	–
8	–	0	0	0 (1)	0	–	–
9	–	1	0	0	2 ^a	–	–
10	–	0	1	–	0	–	–
11	–	0	–	–	–	–	–
12	–	0	–	–	–	–	–

Note.—Lesion score on unenhanced images was determined by using T2-weighting and a semiquantitative scoring system [5]; the score represents the number of lesions to date. Numbers in parentheses indicate the total number of enhancing lesions (new, persistently enhancing, and one [case 4, 8th month] reenhancing) on that month's MR images in cases in which the lesions that enhanced were not all new lesions. Dashes = no examination.

^a Times of clinical relapses.

hancement was noted (Fig. 4). Of the new enhancing lesions, 34 were smaller than 5 mm and 16 were larger. Most (94%) of the enhancing lesions were located supratentorially, with 27 in the left hemisphere and 20 in the right; most were located in the frontal ($n = 25$) and parietal ($n = 16$) lobes. Only eight (16%) of the new enhancing lesions were periventricular (Fig. 2).

Four lesions were not visible on the corresponding T2-weighted images, and three others (two of which were in the gray matter) were recognized only with great difficulty (retrospectively) and otherwise probably would not have been seen. Of the remaining 43 lesions that were shown on T2-weighted images, 31 were clearly visible and 12 were poorly seen. Most new lesions appeared in the supratentorial deep white matter. A total of 21 lesions (49%) seen on the T2-weighted images disappeared in a mean time of 3.5 months (SD, 2.7 months; range, 1–9 months). In several instances, lesions became very small, were absent on one set of images, then reappeared, and finally disappeared completely. Of the lesions that eventually disappeared, 80% were initially smaller than 5 mm; of the lesions that eventually remained visible, 48% were initially larger than 5 mm (χ^2 -test = 4.2, $p = .04$). The mean follow-up time for lesions that remained visible (10 clearly, 13 poorly, and three retrospectively) was 5.3 months (SD, 2.4 months; range, 1–9 months). One lesion was first seen on the last set of images (no follow-up). Interestingly, one lesion was not seen on the initial T2-weighted images, but became visible (and remained so) on follow-up images. A generally

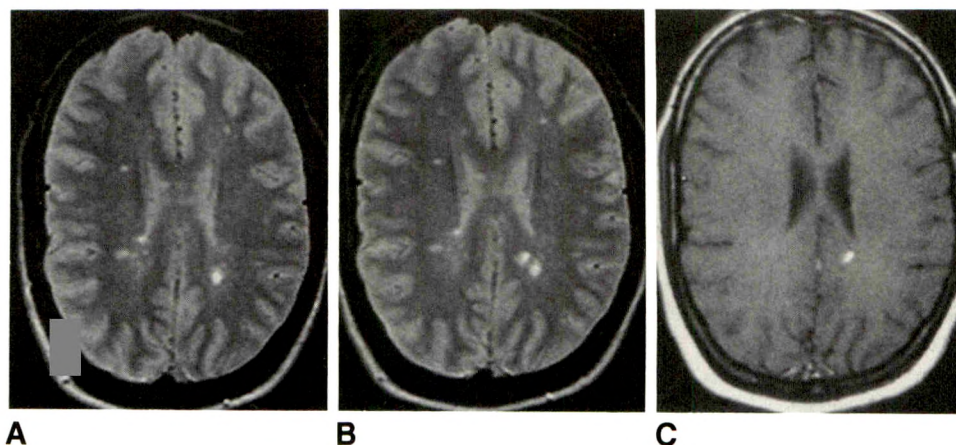


Fig. 2.—Case 3.
A, Unenhanced T2-weighted MR image shows several white matter lesions that did not enhance on T1-weighted image (not shown) after administration of contrast material.
B and C, Subsequent unenhanced T2-weighted MR image (B) and contrast-enhanced T1-weighted image (C) show development of periventricular lesion.

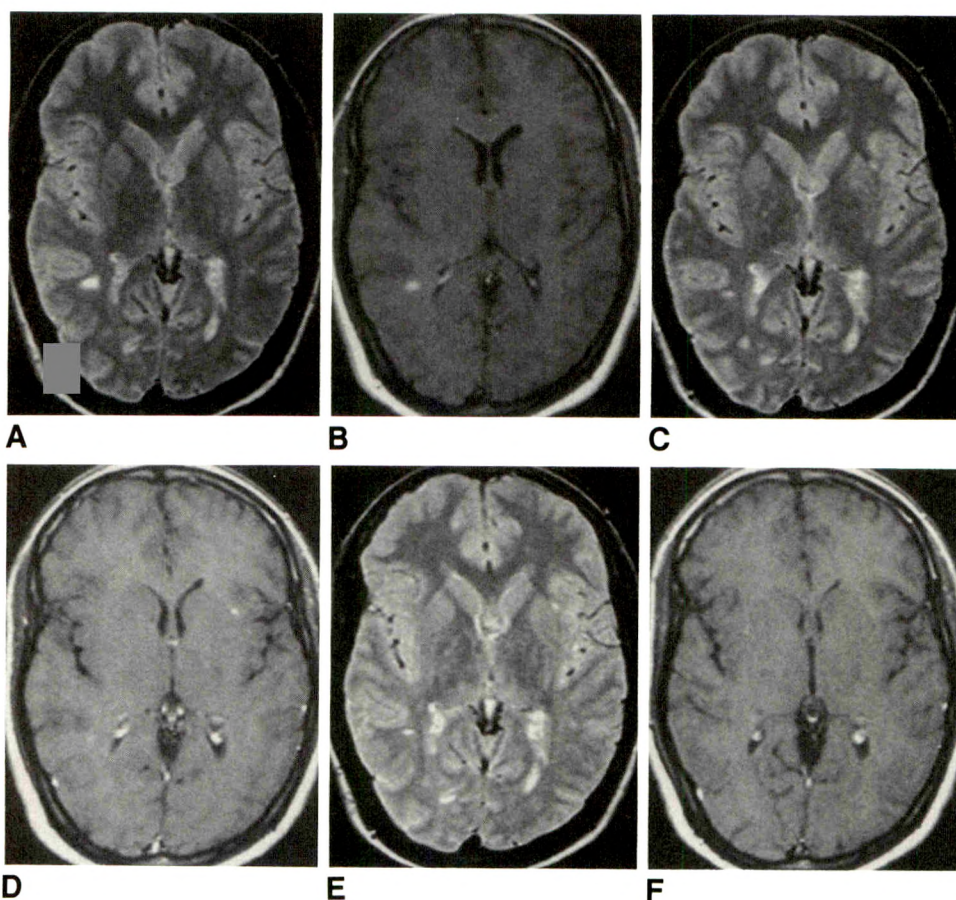


Fig. 3.—Case 3.
A and B, Unenhanced T2-weighted MR image (A) at level of basal ganglia shows a new lesion in right temporal lobe that is hyperintense and not sharply demarcated. Lesion is enhanced on T1-weighted image (B) obtained after administration of contrast material.
C and D, 1 month after A and B. Lesion is considerably smaller on unenhanced T2-weighted image (C) and does not enhance on T1-weighted image (D) obtained after administration of contrast material. A new lesion is seen in left external capsule on T2-weighted image (C), which enhances with contrast material on T1-weighted image.
E and F, 2 months after C and D. Lesions are still present on unenhanced T2-weighted MR image (E) but do not enhance on T1-weighted image (F) obtained after administration of contrast material.

recognized pattern was that new lesions were not very sharply demarcated and hyperintense on the T2-weighted images at first, but became a little smaller, better demarcated, and less intense on the first set of follow-up images (Fig. 3). On follow-up images, the sizes and signal intensity of the lesions usually decreased, and the lesions sometimes totally disappeared.

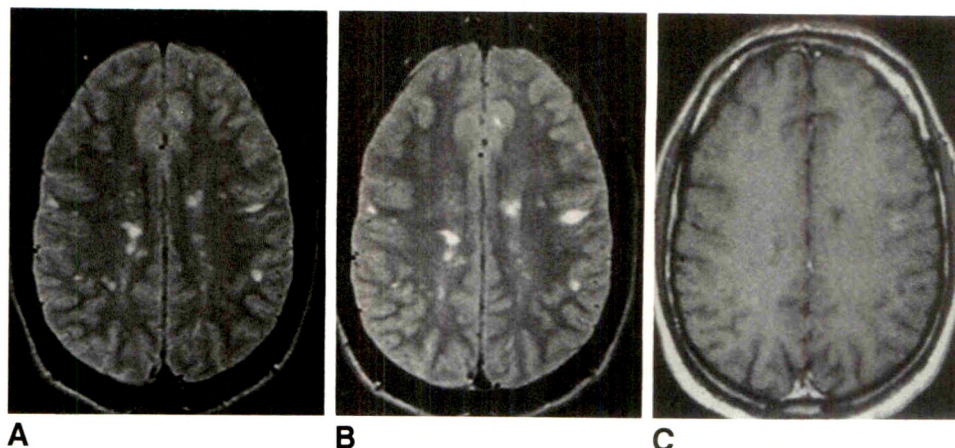
Clinical and MR Imaging Correlation

The timing of the clinical relapses is indicated in Table 1. All five clinical relapses occurred at times when contrast-enhancing lesions were seen on MR images. On the other hand, on 21 occasions, new contrast enhancement or re-enhancement was seen in patients when no clinical relapse was

Fig. 4.—Case 5.

A, Unenhanced T2-weighted MR image shows multiple lesions.

B and C, 1 month after A. Unenhanced T2-weighted image (B) shows clear growth of left frontal lesion, and ring enhancement at periphery of lesion is seen on T1-weighted image (C) obtained after administration of contrast material.



occurring. The kappa coefficient for interobserver agreement (contrast enhancement vs clinical relapse) was 0.21 (0 means no agreement, 1 means complete agreement). In one patient, seven lesions enhanced on more than one occasion, around the time of the patient's first clinical relapse. The patients who initially had optic neuritis showed substantially more new lesions than did those who initially had somatosensory symptoms. In two of the three patients who had a somatosensory relapse, new lesions were found in the contralateral parietal region, but in the third the only new lesion was found in the temporal lobe. In the other two patients who had relapses, the clinical signs and symptoms were confined to regions outside the brain (bladder and optic nerve), but new brain lesions were seen on MR images nevertheless.

Discussion

One of the most striking findings in this study, as in previous studies on the same subject [1–3, 5–7], is the considerable amount of so-called silent disease activity. The kappa coefficient for interobserver agreement (presence of contrast-enhancing lesions vs clinical relapses) was poor. The reason is that, although all the clinical relapses occurred at a time when new enhancing lesions were present, only 19% of the new lesions seen on MR images were associated with clinical disease activity. Enhancement lasted less than 2 months in 86% of the lesions, and enhancement for more than 2 months was seen in only 4%, which is in accordance with findings of previous studies [5–7].

The use of gadopentetate dimeglumine led to the detection of seven new lesions (not visible or only retrospectively visible compared with 43 lesions that were clearly visible on the T2-weighted images), one reenhancing lesion, and nine lesions with persistent enhancement (detection of 40% more disease activity with contrast enhancement). An additional advantage is that contrast-enhanced images can provide information about changes that appear to be equivocal on T2-weighted images, especially in cases of suboptimal repositioning or of large numbers of preexisting lesions. Our results support the concept that sequential contrast-enhanced MR imaging fre-

quently shows clinically silent disease activity in relapsing-remitting MS.

New lesions were seen preponderantly in the supratentorial deep white matter, despite the characteristic finding of periventricular white matter lesions in MS (see, for example, diagnostic MR criteria for MS by Paty et al. [17]). We found a poor correlation between the initial lesion score and the subsequent development of new enhancing lesions. The three patients who initially had optic neuritis had a higher frequency of new lesions seen on brain MR imaging than did the patients who initially had somatosensory symptoms.

The follow-up examinations showed that 49% of the lesions seen on T2-weighted images eventually disappeared, especially smaller lesions. Disappearance of lesions is a controversial subject. At this time, it is impossible to decide whether lesions completely resolve or just disappear beyond the resolution of the imaging systems. For new lesions to be detected with certainty (Figs. 2–4), identical slice repositioning is essential (Fig. 1). Quantitative assessment of reproducibility would be preferable, but as this is difficult to perform, we chose to assess reproducibility in a subjective fashion. More than 75% of the repositioning was graded as good. On those MR images, the inaccuracy in any direction was less than half a slice in thickness, or 2.5 mm. As the width of the brain is at least 12 cm, this implies an angulation error of less than 1.2° ($\tan^{-1} [2.5/120]$). The "reappearance" of some small lesions that were not seen on the initial T2-weighted images may be related to small fluctuations in repositioning accuracy, resulting in artificial disappearance of smaller lesions in the interslice gap or as a result of volume averaging with normal-appearing brain tissue and subsequent loss of contrast. In two patients in whom repositioning was less successful, the anatomic landmarks chosen could have been difficult to detect, or, alternatively, it may have been difficult for the patients to lie still during the examination. Perhaps in the future the entire brain can be imaged with three-dimensional acquisitions, imaging it within a reasonable period of time, allowing the choice of an arbitrary plane of evaluation on postprocessing.

In MS, an exacerbation (bout, episode, attack) is defined as the occurrence of a symptom or sign of neurologic dysfunction, with or without clinical confirmation, that lasts longer

TABLE 2: Serial MR Imaging Studies of the Brain in Patients with Multiple Sclerosis

Reference No.	Disease Course	No. of Patients	Mean Age (yr)	Mean EDSS on Entry	Field Strength (T)	Mean Duration of Disease (months)	Sex Ratio (F/M)	Clinical Relapse Rate per Month	Contrast Medium Used	Rate of Progression	No. of New Lesions per Month
[1]	RR	7	27	3.0	0.15	5.7	2.5 ^a	0.12	No	0.53	0.50
[3]	RR	9	30	0.5	0.15	5.0	1.3	0.04	No	0.10	0.20
[2]	SP ^b	8	45	6.1	0.15	15.0	1.0	0	No	0.41	1.00
[5]	SP	12	35	5.2	0.5	7.8	0.5 ^a	0.28	Yes	0.67	1.50
[7]	RR	6	34	1.9	1.5	1.4	5.0	0.03	Yes	1.36	3.35
[6]	RR	5	30	3.0	0.5	4.0	4.0 ^a	0.27	Yes	0.75	1.46
This study	RR	7	24	1.6	0.6	2.7	1.3	0.10	Yes	0.59	0.86

Note.—EDSS = Expanded Disability Status Scale score, rate of progression = EDSS score/duration of disease, RR = relapsing-remitting, SP = secondary progressive.

^a Information about the number of men and women was not provided in the original papers, but was later obtained by personal communication.

^b In one patient, the course of disease was primary progressive.

than 24 hr [13]. The number of exacerbations, defined in this way, is widely used as a parameter in treatment trials. In our patients, the number of new enhancing or reenhancing lesions detected with MR imaging was 4.2 times the number of clinical relapses. Subjective clinical scoring systems, such as the widely used Expanded Disability Status Scale [14], have a high interrater variability [18, 19]. This means that a large change (1.0 point) in score (on a scale of 0–10) is necessary to show a clinically significant change in the disease course [18]. This could imply that moderately effective treatments are not appreciated as such, because the measure of outcome (Expanded Disability Status Scale score) is not sensitive enough. During the study period, a change in the Expanded Disability Status Scale score of at least 1.0 point occurred in only three of five relapses, and all exit scores were identical to the entry scores, whereas a substantial amount of disease activity was detected with MR imaging.

Several sequential MR studies have been performed in MS with different disease courses. It has been shown that patients with relapsing-remitting and secondary progressive MS (together, 85% of the patients) frequently have new lesions. Table 2 gives an overview of these studies [1–3, 5–7] and of the present study. One of the most striking points is the enormous variation in the number of new lesions per month. For example, in four studies, patients with relapsing-remitting MS with a relatively short duration of disease were examined, and the mean number of new lesions per month varied from 0.2 to 3.4 (factor 17). Several technical and clinical parameters of those studies are also listed and show substantial inhomogeneity. We performed a weighted (by the number of patients per study) multiple regression analysis with the mean number of new lesions as the dependent variable and field strength, duration of disease, sex ratio, relapse rate, use of contrast material, and progression rate (defined as Expanded Disability Status Scale score/disease duration) as the independent variables. The fitted model explained most (89%) of the variance in the mean number of new lesions. The variance explained by field strength was 28%, by disease duration 28%, by sex ratio 2%, by relapse rate 8%, by use of contrast material 12%, and by progression rate 26% (percentages do

not by definition have to add up to 89% or 100%). This regression analysis thus shows that a substantial part of the variance in the mean number of new lesions per patient in those studies can be explained by variations in the parameters listed in Table 2. Causal relationships, however, are not shown by this analysis, as for example, field strength is strongly correlated with geographic distribution of the imaging centers involved. It does show, however, that differences in several clinical factors, among them duration of disease and rate of progression, account for a fair amount of the variance between different studies. The analysis suggests that homogeneity in study design should extend from technical to clinical design. In addition to the selection of a homogeneous study group according to the disease course [5, 6], matching of other clinical factors between treatment and placebo groups in order to increase precision might be needed as well.

In conclusion, our results support the concept that contrast-enhanced MR imaging is more sensitive than clinical monitoring in detecting new disease activity in relapsing-remitting MS. If we assume that the development of new abnormalities seen on MR images will ultimately be accompanied by clinical deterioration, then sequential contrast-enhanced MR imaging might be used to measure outcome in pilot studies of putative therapeutic regimens, as it could reduce the number of patients and the follow-up time needed to demonstrate a treatment effect.

ACKNOWLEDGMENTS

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New Format for Abstracts

Beginning immediately, the *AJR* will publish abstracts of articles in a different format, much like the ones recently adopted by the *New England Journal of Medicine* and the *Journal of the American Medical Association*. The purpose of the new design is to have abstracts present the essential elements of articles more clearly and concisely. The contents, organization, and length of the abstracts will be the same as before; however, rather than being all one paragraph except for the conclusion, abstracts will now be divided into four paragraphs, each with a title: objective, subjects (or materials) and methods, results, and conclusion.

The *AJR* Guidelines for Authors, which appears at the front of every issue of the Journal, has been revised to help you write abstracts in this new format. Authors should familiarize themselves with these guidelines and incorporate them into all manuscripts submitted for publication.

Robert N. Berk
Editor-in-Chief

Book Review

Imaging of the Temporal Bone, 2nd ed. By Joel D. Swartz and H. Ric Harnsberger. New York: Thieme, 353 pp., 1992. \$99

Dr. Harnsberger has joined Dr. Swartz in producing the second edition of what has become a standard textbook of temporal bone imaging. Although this new offering has been expanded by 150 pages, it remains a convenient reference for this challenging anatomic region. A superficial glance confirms that the organization of this edition is similar to that of the previous edition. The authors systematically review major anatomic regions of the temporal bone: the external auditory canal, the middle ear, and the inner ear. The vascular anatomy of the temporal bone, trauma, and cerebellopontine angle, and the facial nerve are described in separate chapters.

A closer examination reveals that several substantive changes have been made in the new volume. Unlike in the first edition, in which MR imaging was reserved for the final chapter, MR now has been integrated throughout the text. The organization of the first chapter is significantly improved by using a clinical symptom or problem-oriented approach rather than an itemized technique approach. Several imaging algorithms, which will be helpful to both inexperienced and seasoned temporal bone radiologists, have been introduced. These algorithms will be useful in consultations with clinical colleagues. In the chapter on the vascular anatomy of temporal bone, a detailed discussion of the evaluation of pulsatile tinnitus has been added. The discussion of vascular lesions in this chapter also has been revised and reorganized. The chapter on the facial nerve is especially well written and contains several excellent drawings and many illustrative cases. The only confusing item is a figure that incorrectly uses the labels from the previous edition. Of particular interest is the MR protocol on facial nerve imaging, which not only recommends the appropriate MR sequences but also clearly states the rationale in a summary table.

As suggested in a published review of the first edition, an excellent atlas of normal CT and MR anatomic findings in multiple planes has been added as an appendix. The scans and images are well documented, with labels that are organized in numerical order at the beginning of the section.

Overall, the book is well written. Statements throughout are thor-

oughly referenced. The bibliographies at the end of each chapter are extensive and current. In several chapters, the references have been significantly expanded compared with those in the earlier edition. As in the first edition, the illustrations are excellent, although in view of the newer CT software available today, a few of the figures are slightly dated. Several new drawings that facilitate an understanding of the complex anatomy of the middle ear have been added. Helpful summary tables are found throughout the book.

One of the most significant and disturbing shortcomings of this otherwise superb effort is the markedly abbreviated and inconsistent index, which hampers retrieval of the book's excellent information. Entries such as "stapes," "malleus," and "incus" have been deleted, and only on further examination did I discover that the general term "ossicles" has been substituted. The word "fractures" is deleted and must be sought under the word "trauma." An important structure such as the sinus tympani, which is discussed in the text, is not even mentioned in the index, unless it is covered in the 10-page section "Temporal Bone, Normal." The helpful format of separately indicating figure references is negated by relatively few figure entries in the index. More difficult to understand is that the number of index entries with page references has decreased almost 25% compared with the first edition.

In summary, the authors present valuable and complex information in a readable and useful style, which justifies the purchase of this second edition of an already superb volume. The book's tightly focused format offers an advantage over larger, bulkier general textbooks on head and neck radiology. Ample interspersed illustrations provides pleasant reading of a difficult subject. *Imaging of the Temporal Bone* should be considered a classic in the literature on the temporal bone and will greatly enhance the practice of otologic imaging.

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Evaluation of Complex Cystic Masses of the Brain: Value of Steady-State Free-Precession MR Imaging

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James MacFall
Ralph Heinz

OBJECTIVE. This study evaluated the effectiveness of steady-state free-precession (SSFP) MR imaging of complex cystic masses of the brain compared with that of conventional T1- and T2-weighted spin-echo imaging. Our hypothesis is that SSFP MR images provide better characterization of these masses and facilitate more appropriate preoperative diagnoses and planning.

SUBJECT AND METHODS. Axial T1-weighted and SSFP MR images and specimens for pathologic examination were obtained in seven consecutive patients, 9–81 years old, with cystic mass lesions of the brain and neurologic symptoms and signs directly related to the masses. Axial contrast-enhanced T1-weighted images were obtained in six patients, surgical exploration was done in five patients, and stereotaxic biopsy was done in two. After examination of the routine spin-echo and SSFP images, the usefulness of SSFP images was determined by how well they facilitated correct preoperative diagnosis.

RESULTS. On SSFP MR images, the solid or inhomogeneous components of a cystic mass had extremely low signals in contrast to the high signal of surrounding fluid. On routine spin-echo images, however, the signals of these components were masked by the signal of the surrounding fluid. SSFP MR images helped markedly in diagnosis of hemorrhagic, epidermoid, and arachnoid cysts. In cases of enhancing brain tumors, SSFP MR images provided the same information that contrast-enhanced images did. Overall, when SSFP MR imaging was used, more information about the texture and constituents of the cystic mass was obtained, and a more useful diagnosis was made.

CONCLUSION. Initial results show that SSFP MR imaging is a more useful technique than conventional spin-echo imaging for characterizing complex cystic masses of the brain. SSFP MR imaging (1) allows distinction of edema from tumor, (2) helps establish where biopsy has the best chance of providing tissue that will show pathologic changes, and (3) helps distinguish simple cysts from tumors, tumor-cyst, or multicompartamental cyst and may be particularly helpful in detecting the contents of hemorrhagic cysts.

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The MR signal intensities of cystic masses of the brain on spin-echo images can be similar to the signal intensities of CSF. On T1-weighted and proton density-weighted images, slight differences between the signal intensities of the masses and those of CSF can usually be distinguished, but the intensities of the masses and of CSF are quite similar on T2-weighted images. A potential drawback of spin-echo images is that they may not reliably show the internal architecture or morphology of cystic masses. If the solid portion does not enhance with contrast material (gadopentetate dimeglumine), the radiologist may find it difficult to determine whether the mass is a simple cyst or a cyst with a solid component. Knowledge of the internal components and constituents of a cystic mass is useful for preoperative diagnosis and planning. Steady-state free-precession (SSFP) [1–3] MR imaging is a fast technique that generates heavily T2-weighted images that may enable improved characterization of complex cystic masses.

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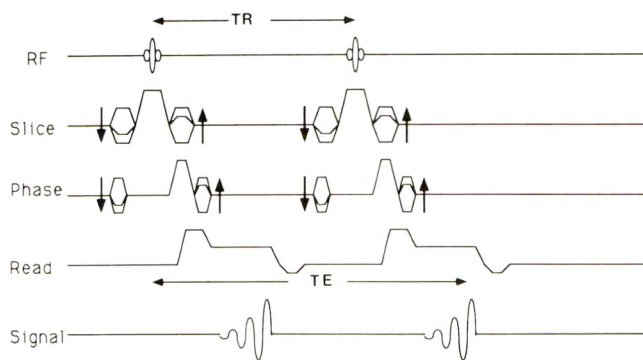


Fig. 1.—Diagram of three-dimensional SSFP pulse sequence. Phase encoding is used on both slice and conventional (in plane) phase axes. Rephasing gradients are applied to maintain steady state. Vertical arrows indicate that as phase-encoding gradients are changed, rephase gradients change in opposite direction. Note that echo time (TE) is longer than repetition time (TR) because each signal is the result of two successive excitations. Constant dephase gradients are applied before each signal on phase and read axes to dephase FID (free induction decay) from the RF pulse. Read gradient balance is adjusted to produce an asymmetric echo, as illustrated, to minimize T2* effects.

Subjects and Methods

Seven consecutive patients (four females and three males) 9–81 years old (mean, 42 years) with cystic mass lesions of the brain had MR imaging. Information about the cystic masses was obtained from outside imaging studies. Each patient had neurologic symptoms and signs directly related to the cystic mass. All studies were performed with a 1.5-T superconducting magnet (Signa, GE Medical Systems, Milwaukee, WI). Initially, we used an axial multislice T1-weighted sequence (600/20/2 [TR/TE/excitations]), 5-mm slice thickness, 1-mm interslice gap, 20-cm field of view, and 192×256 matrix. Gradient-moment nulling without cardiac gating was used on long TR images (2800/30.80/1). In selected patients, additional T1-weighted sagittal and coronal images were obtained in order to provide more anatomic detail. In all seven patients, axial volume SSFP MR images were obtained by using the following parameters: 26/48/2 (note that TE is longer than TR for SSFP), 256×128 matrix, 20-cm field of view, 2-mm slice thickness without gap, 90° flip angle, and 32 slices, with a scan time of 3 min 34 sec. In our experience, SSFP images of control subjects had excellent CSF signal-to-noise ratios at a 90° flip angle. Axial contrast-enhanced (0.1 mmol/kg gadopentetate dimeglumine, Magnevist, Berlex, Cedar Knolls, NJ) T1-weighted images were

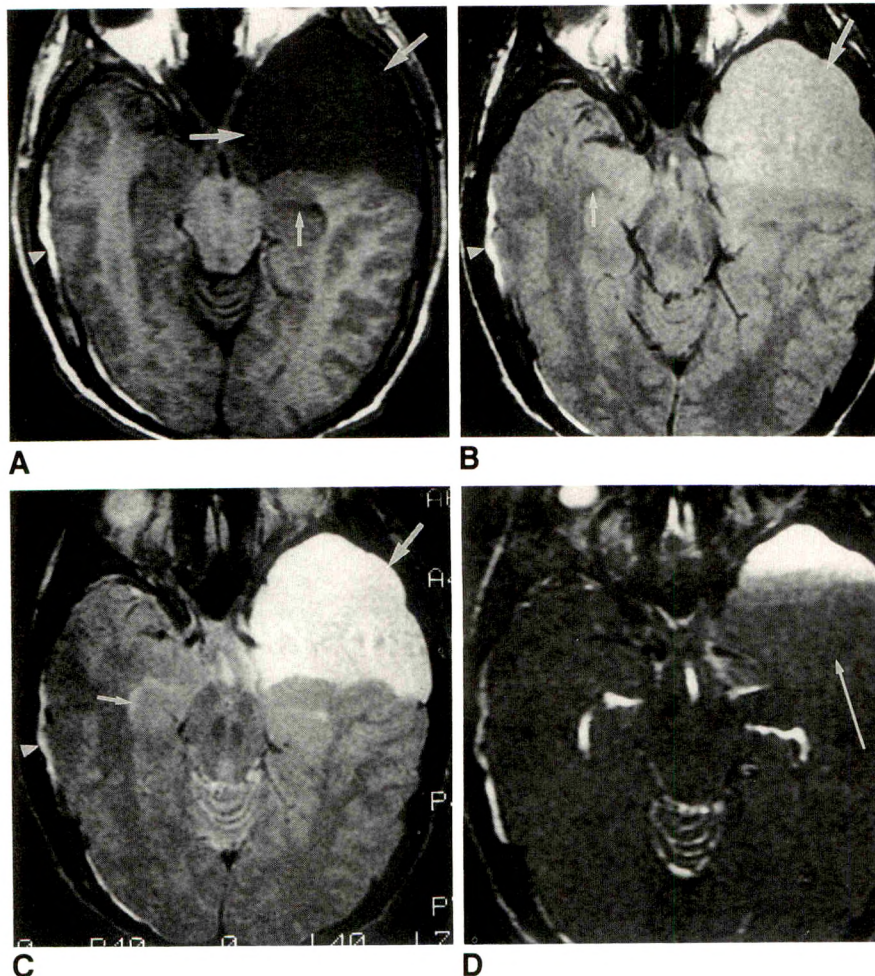


Fig. 2.—23-year-old man who had headache after a blow to his head.

A, Axial T1-weighted (600/20/2) MR image shows large left temporal cyst (large arrows) with some mass effect. Left temporal horn (small arrow) is slightly displaced posteriorly. Note subdural hematoma (arrowhead) on right.

B and C, Axial MR images show cyst (large arrows) is slightly hyperintense relative to CSF in temporal horn (small arrows) on proton density-weighted image (2800/30/1, B) and isointense with CSF on T2-weighted image (2800/80/1, C). Hyperintense signal of subdural hematoma (arrowhead in A, B, and C) is due to extracellular methemoglobin.

D, Axial SSFP (26/48/2) MR image of cyst shows two distinct compartments: Upper part has same signal intensity as CSF, whereas lower part (arrow) is markedly hypointense relative to CSF. On basis of this image, a complicated cyst such as a hemorrhagic cyst was considered. At surgery, a cyst was found, which contained serosanguineous fluid. Right globe is hyperintense, and left globe is hypointense. This is due to phase artifact from motion of globes. SSFP pulse sequence is extremely sensitive to motion and can create phase artifact.

also obtained in six patients. Surgical exploration was done in five patients, and stereotaxic biopsy was done in two. Specimens for pathologic examination were obtained from all seven patients. Both the routine spin-echo images and the SSFP images were compared and evaluated by two experienced neuroradiologists. All images were displayed on consoles, and window width and levels of each image were chosen for comparison. The usefulness of SSFP and spin-echo images was determined by how accurately they enabled correct preoperative diagnosis.

Figure 1 shows the SSFP sequence used. It is a conventional three-dimensional sequence with the read gradient waveforms modified to image the echo formed just before the RF pulse.

Results

Generally, SSFP images showed differences between the solid or inhomogeneous components of a cystic mass and fluid compartments better than spin-echo images did. In this study, on SSFP images, such components had an extremely low signal in contrast to the high signal of surrounding fluid. On routine spin-echo images, however, the signals of these inhomogeneous components were masked by the signal of the surrounding fluid. Thus, more information about the tex-

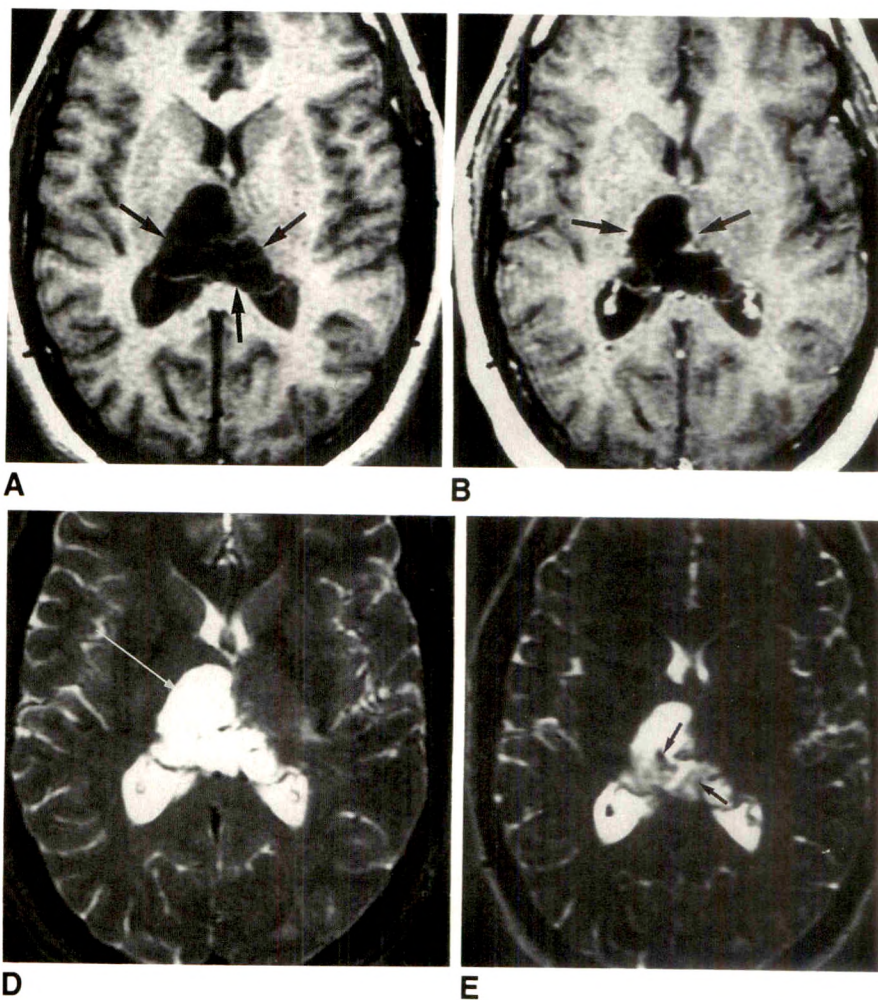
ture and constituents of the cystic mass was obtained and a more useful diagnosis was made when SSFP imaging was used.

In a patient with hemorrhagic temporal arachnoid cyst (Fig. 2), an SSFP image showed a fluid-fluid level, with the lower dark signal representing serosanguineous fluid within the cyst. Spin-echo images showed only a homogeneous cyst with a signal like that of CSF. On the basis of SSFP images, a hemorrhagic cyst was considered, and during surgery, dark bloody fluid was found.

A second patient had a cystic mass in the third ventricular velum interpositum cerebri (Fig. 3). SSFP images showed the central inhomogeneous components better than spin-echo images did. Images obtained after administration of contrast material did not show any marked enhancement within the mass. On the basis of the supplemental SSFP images, epidermoid cyst was considered, and pathologic examination of specimens confirmed the diagnosis.

In an elderly woman, spin-echo images showed a large mass in the right parietal region with a signal similar to that of CSF (Fig. 4). SSFP images clearly showed the solid components within that mass, and the components correlated

Fig. 3.—35-year-old man with headache.
A, Axial T1-weighted (600/20/2) MR image shows lobulated hypointense mass (arrows) in region of velum interpositum cerebri.
B, Axial T1-weighted (600/20/2) image obtained with contrast material shows that mass slightly enhances in its peripheral portions (arrows).
C and D, Axial proton density-weighted (2800/30/1, C) and T2-weighted (2800/80/1, D) MR images show mass (arrows) has signal intensity similar to that of CSF.
E, Axial SSFP (26/48/2) MR image shows low-signal-intensity inhomogeneous parts (arrows) within mass.
Epidermoid cyst was considered because of shape and signal intensities of mass. Pathologic examination of a surgical specimen confirmed diagnosis.



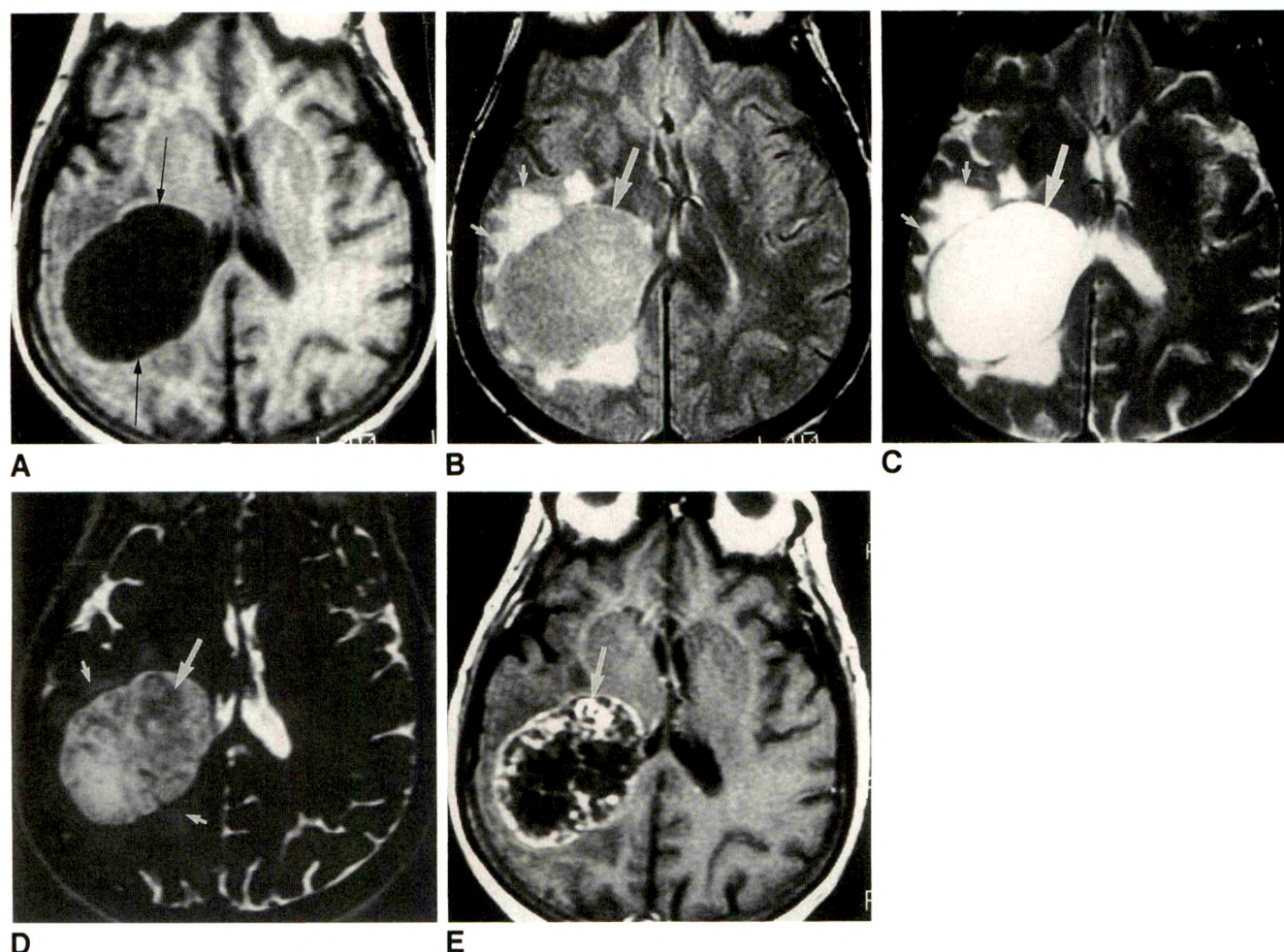


Fig. 4.—81-year-old woman with headache and ataxia.
 A, Axial T1-weighted (600/20/2) MR image of brain shows $4.5 \times 4.0 \times 4.0$ cm, low-signal-intensity mass (arrows) with a smooth border in right cerebral hemisphere adjacent to right posterolateral ventricle. Right temporoparietal sulci were effaced by mass effect.
 B and C, Axial MR images at same level as A show mass (large arrows) is slightly hyperintense relative to CSF on proton density-weighted image (2800/30/1, B) and isointense with CSF on T2-weighted image (2800/80/1, C). Note peritumoral edema (small arrows). Mass is homogeneous in signal intensity on both B and C.
 D, Axial SSFP (26/48/2) image at same level as A shows mass is inhomogeneously hypointense relative to CSF and hyperintense relative to brain parenchyma. Interior of mass has areas of irregular hypointensity indicating complex internal architecture (large arrow). Peritumoral hyperintensity (small arrows) represents edema.
 E, Axial T1-weighted (600/20/2) MR image obtained with contrast material and at same level as A shows mass (arrow) is inhomogeneously enhanced. Enhancing part has similar distribution as hypointense areas of mass shown on SSFP image (D).
 After examining imaging findings, we considered a complicated cystic mass, such as primary brain tumor or metastasis. Pathologic examination of a surgical specimen showed metastatic adenocarcinoma from gastrointestinal tract.

with the enhancing part of the mass seen on images obtained with contrast material. A complicated mass such as primary brain tumor or metastasis was considered, and pathologic examination of a surgical specimen showed metastatic adenocarcinoma.

A middle-aged woman also had a mass in the right parietal region that was hypointense on T1-weighted images and hyperintense on T2-weighted images (Fig. 5). The peripheral part of the mass and surrounding edema had a similar signal intensity on spin-echo images. However, on SSFP images, the thick wall of the mass with its low signal intensity could easily be distinguished from the mildly hyperintense surrounding edema. The thick wall showed enhancement on images

obtained with contrast material. Stereotaxic biopsy of the wall was done, and the diagnosis was glioblastoma multiforme.

Two patients had suprasellar cystic lesions. On conventional spin-echo images, the lesions had signal intensity similar to that of CSF. SSFP images confirmed the homogeneous CSF-like component in the first patient, and a simple arachnoid cyst was considered. In the second patient, SSFP images showed a small component of low signal intensity in the cystic mass. An arachnoid cyst with a single small loculated compartment was considered. In both cases, surgery confirmed the diagnosis made from SSFP imaging findings.

In a 9-year-old girl with a suprasellar cystic mass (Fig. 6), SSFP images showed the solid components of the mass

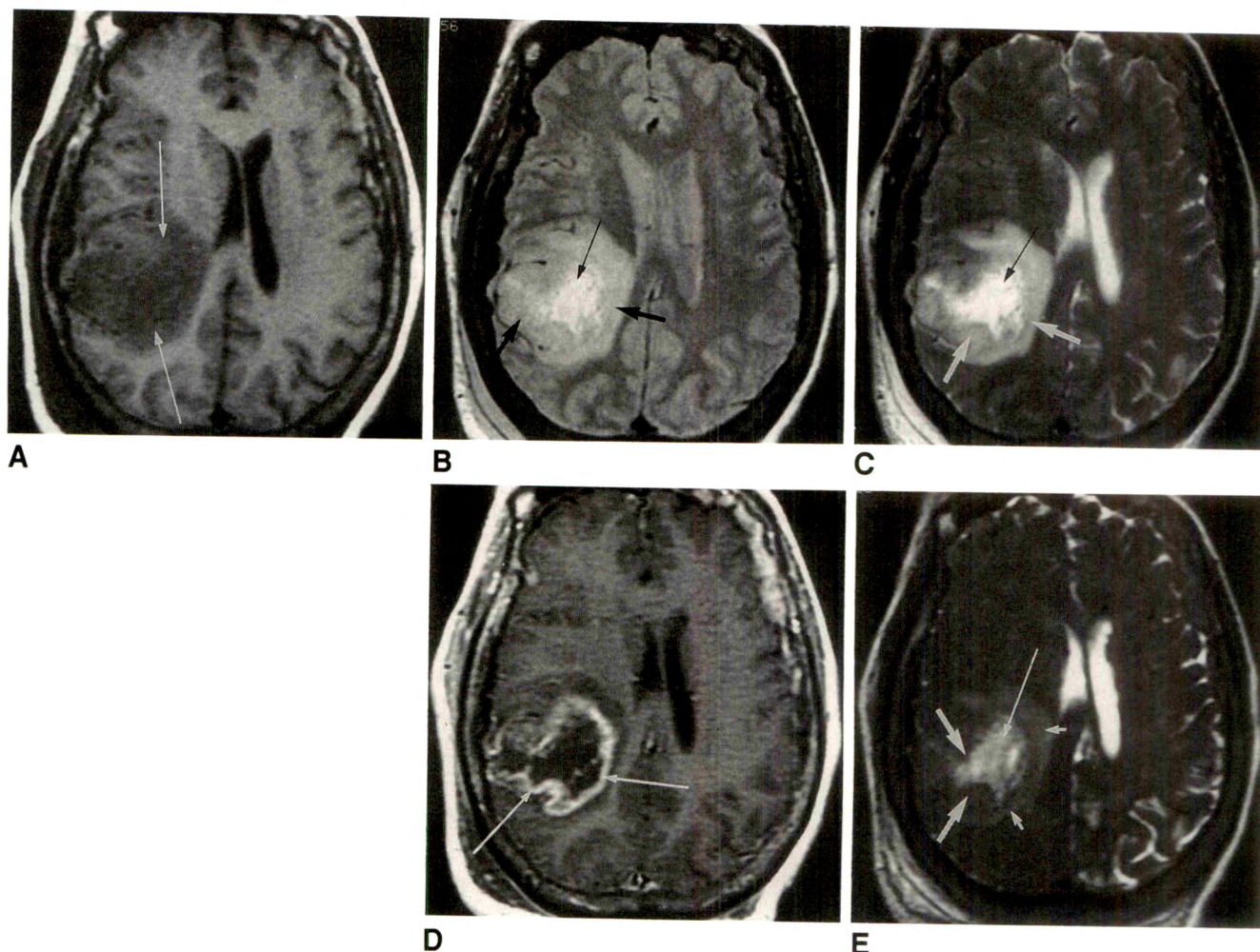


Fig. 5.—51-year-old woman with altered mental status.

A, Axial T1-weighted (600/20/2) MR image shows area of hypointensity (arrows) with some mass effect in right parietal lobe.

B and C, Axial MR images show center part of mass is hyperintense (long thin arrows) relative to CSF on both proton density-weighted (2800/30/1, B) and T2-weighted (2800/80/1, C) images. Peripheral part of mass (short thick arrows) is slightly hyperintense relative to CSF on B and slightly hypointense relative to CSF on C. Center part might represent necrotic part of mass; however, it is difficult to distinguish peripheral part of mass from surrounding edema.

D, Axial T1-weighted (600/20/2) image obtained with contrast material shows mass is inhomogeneously enhanced in its periphery (arrows).

E, Axial SSFP (26/48/2) MR image shows central part of mass (long thin arrow) is hyperintense relative to parenchyma. Note peritumoral edema (large thick arrows) in superior and medial borders of mass. Superolateral and inferior parts (small arrows) of mass, which represent solid components, are isointense (and blend) with parenchyma.

Distinction between edema and solid part of tumor is better shown on SSFP image. In addition, wall of this mass appeared thicker on SSFP image than on axial contrast-enhanced T1-weighted image. An aggressive necrotic brain tumor such as glioblastoma multiforme was diagnosed on the basis of imaging findings. Specimen obtained by guided stereotaxic biopsy from inferior thicker wall seen on SSFP image showed glioblastoma multiforme.

better than the unenhanced spin-echo images did. This solid component seen on SSFP images showed enhancement on images obtained after administration of contrast material. Juvenile pilocytic astrocytoma was considered and was confirmed by examination of a pathologic specimen.

SSFP images significantly aided diagnosis of hemorrhagic, epidermoid, and arachnoid cysts. With respect to enhancing brain tumors (metastasis, glioblastoma multiforme, and juvenile pilocytic astrocytoma), SSFP images showed the part of the tumor that was enhanced on images obtained after administration of contrast material and essentially provided the same information that the contrast-enhanced images did.

Discussion

SSFP imaging [1–3] is a fast imaging method that allows the acquisition of heavily T2-weighted images with less T2* weighting than other fast imaging techniques, such as GRASS (gradient-recalled acquisition in the steady state), FISP (fast imaging with steady-state precession), and FLASH (fast low-angle shot), which also use a long TE. This is because the SSFP sequence can image the echo that is always potentially formed in fast imaging but is usually dispersed by spoiling gradients or RF phase modulation. The echo would naturally form at the position of the RF excitation, but it is deliberately

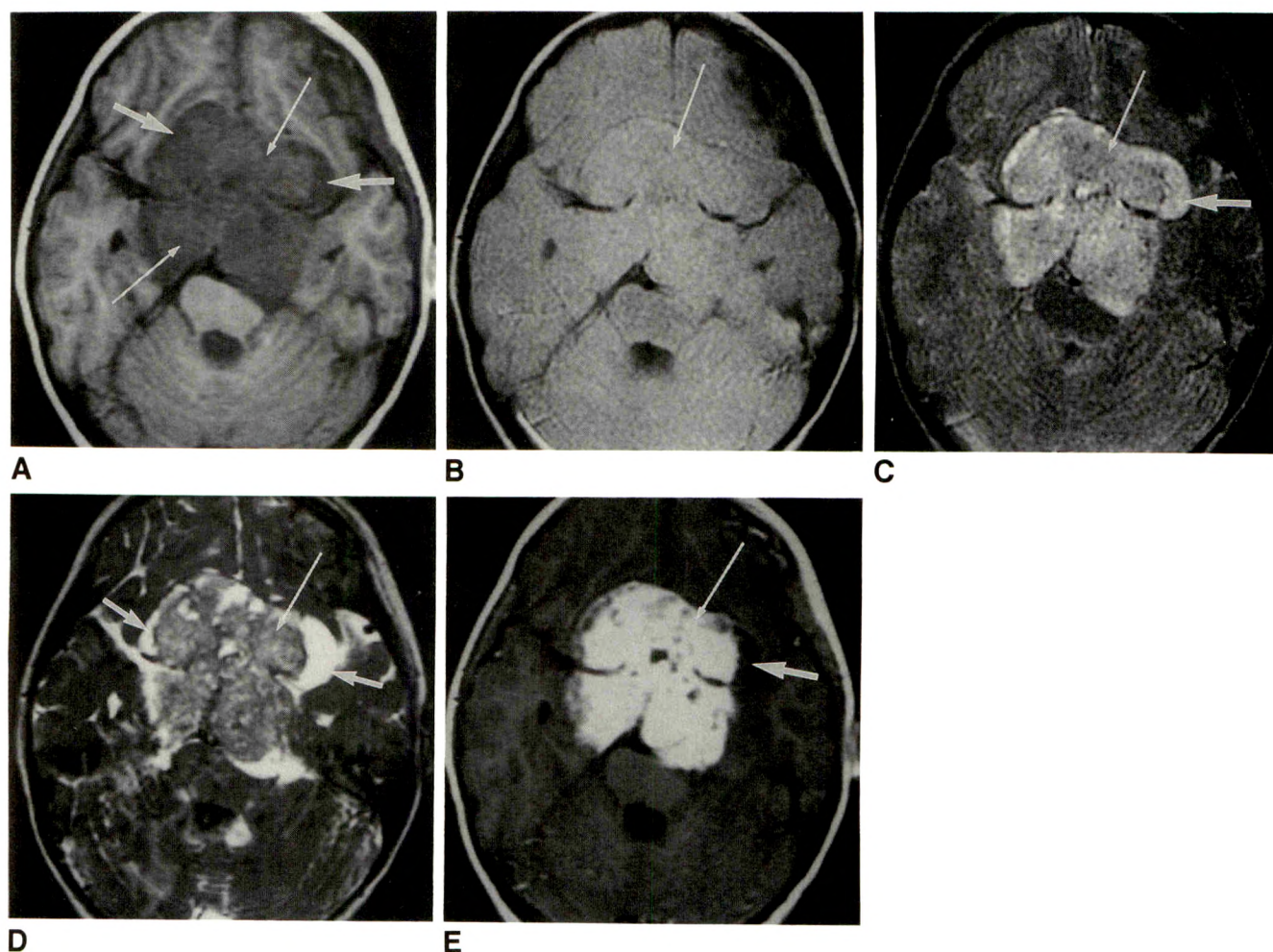


Fig. 6.—9-year-old girl with headache, visual field defect, and endocrine dysfunction.

A, Axial T1-weighted (600/20/2) MR image shows 5 × 5 × 4 cm lobulated hypointense mass (*long thin arrows*) with markedly hypointense border (*wide arrows*).

B and C, Axial MR images show mass is almost isointense (*arrow*) with brain on proton density-weighted image (2800/30/1, B) and slightly hyperintense (*long thin arrow*) relative to brain and has a hyperintense rim (*wide arrow*) on T2-weighted image (2800/80/1, C).

D, Axial SSFP (26/48/2) MR image shows mass is inhomogeneously hyperintense (*long thin arrow*) relative to brain. Signal contrast between mass and surrounding rim (*wide arrows*), which has signal intensity like that of CSF, is high.

E, Axial T1-weighted MR image obtained with contrast material shows intensely enhanced tumor (*long thin arrow*) with peripheral cystic component (*wide arrow*).

On basis of imaging findings, a suprasellar hypothalamic juvenile pilocytic astrocytoma with peripheral cystic component was considered. Pathologic examination of a surgical specimen confirmed imaging diagnosis.

shifted away from this position by adjustment of the readout gradient balance. This results in an echo still sensitive to magnetic field inhomogeneity. However, it has no more sensitivity than a short TE fast scan has.

When imaging is done with short TE GRASS or FISP sequences, many tissues have signal enhancement because residual transverse magnetization participates in the establishment of the steady state. This happens even with larger flip angles and may diminish contrast between bordering tissue and fluid compartments. This contrast is dependent on the T1/T2 ratio. With SSFP, the use of longer TE values reduces participation of the transverse magnetization in the development of the steady-state signal for materials with shorter T2. Hence, increased contrast can be developed

between CSF and materials with a shorter T2, such as normal brain parenchyma, the solid components of a cyst, or certain blood products. This contrast is maximized for larger flip angles near 90°, because this maximizes the transverse magnetization contribution for the CSF. Therefore, the use of a large flip angle (90°) and a moderately long TE (≈40 msec) allows acquisition of images with extremely low signal from the brain and abnormal tissues with moderate T2 values (less than 80 msec) and extremely high signal from CSF. The use of three-dimensional techniques helps retain good signal-to-noise ratios in the images despite the long TE, short TR, and large flip angle. The three-dimensional SSFP sequence tends to be more sensitive to motion than other sequences are because it has a longer imaging time (compared with single-

slice techniques) and a mixed signal of transverse magnetization from several excitations. Also, the artifacts are somewhat more visible because the signals from normal tissues are significantly suppressed with large flip angles. Frequently, these artifacts can be minimized by choosing an imaging plane that avoids regions that have large amounts of CSF flow or motion (such as in the orbits). When CSF motion is marked, the coherence of the transverse magnetization is lost, thereby reducing or destroying enhancement of signal from CSF. Thus, the sequence is most useful in cystic regions that do not have marked flow of the fluid component.

With SSFP imaging, the signal intensities of all solid tissues are typically suppressed, which makes differentiation between abnormal tissue and brain parenchyma especially difficult. Immobile CSF always has a high signal intensity on SSFP images. These characteristics restrict the usefulness of SSFP images in neuroradiology [4]. However, the use of longer TEs causes a reduction of transverse magnetization in the development of steady-state signals for materials with shorter T2 and enables us to show the solid and hemorrhagic portions of a mass with signal intensities lower than that of CSF. In addition, heavily T2-weighted SSFP images can show the high-signal-intensity fluid component of cystic masses. Therefore, inhomogeneous or solid components of these masses can be distinguished from the fluid components. In much the same way, SSFP imaging can help distinguish between tumor and peritumoral edema because edema tends to have a slightly higher signal intensity than tumor.

As shown in one patient (Fig. 2), SSFP imaging is helpful in cases of simple arachnoid cyst, which usually has a signal intensity like that of CSF. In this case, the cyst had a blood component with a lower signal intensity than that of the CSF fluid. Hemorrhagic cysts therefore can be detected with SSFP imaging. CT can be performed to confirm the presence of blood products in the cyst. In another patient, an epidermoid cyst was diagnosed on the basis of imaging findings (Fig. 3): irregular borders of the mass, relatively less significant mass effect and peritumoral edema, absence of hydrocephalus on spin-echo images, and diminished signal intensity of the internal part of the cyst on SSFP images. Long TR spin-echo images can show some abnormally decreased signal intensity in epidermoid cysts, but not as clearly as SSFP images can. In another case, the long and short TR images did not show internal texture of the mass at all (Fig. 4), and the diagnosis was a homogeneous cystic mass. Interestingly, this mass

showed contrast enhancement, and the enhancing parts matched the parts that had hypointense signal on SSFP images. These contrast-enhanced portions of T1-weighted images, of course, showed some solid components in the mass. However, if this solid component had not enhanced with contrast material, the solid component of the cystic mass would not have been detectable.

Tsuruda et al. [5] examined the usefulness of diffusion-weighted MR images of the brain for distinguishing extraaxial arachnoid cysts from epidermoid tumors. On apparent-diffusion coefficient images, the signal intensity of arachnoid cyst was similar to that of stationary water, whereas that of epidermoid tumors was similar to that of brain parenchyma. In addition, the tumors appeared to be solid and had a slower diffusion rate than the cysts. The SSFP images in our study provided similar information and with better spatial resolution than that of diffusion images. In addition, SSFP images can be obtained in only 3 min 34 sec without postimaging processing.

In conclusion, our preliminary results show that SSFP images are helpful in distinguishing (1) solid and hemorrhagic components of cystic masses and (2) tumor from adjacent edema. Both these distinctions are much more difficult to make when spin-echo images are used. If hemorrhage is suspected after examination of SSFP images, CT should be performed to detect blood products in the cyst. The results of SSFP MR imaging of simple and complex cystic masses can help radiologists and surgeons establish more accurate preoperative diagnoses and more appropriate treatment plans.

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Fusion. Carmel, CA, 1992

Tahnee Marsh¹



This photograph was taken in daylight with film that is sensitive to infrared and the longer (red) wavelength end of the visible spectrum. Because all living things emit infrared rays, plants and other objects have a ghostly glow in the finished photograph. The photographer used a #24a red filter, which blocks some of the visible light from hitting the film, thereby increasing the infrared, or grainy, look.

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The Value of Cerebral Angiography in Predicting Cerebral Ischemia During Carotid Endarterectomy

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OBJECTIVE. Temporary occlusion of the carotid artery during endarterectomy can result in ipsilateral cerebral ischemia if collateral blood flow is insufficient. This requires placement of a shunt across the carotid bifurcation, which is associated with increased operative risk. We retrospectively analyzed preoperative cerebral angiograms and intraoperative electroencephalographic recordings to determine if ischemia during carotid endarterectomy could be predicted from angiographic data.

MATERIALS AND METHODS. The cerebral angiograms of 30 patients were examined. Collateral blood flow to the hemisphere on the side of surgery was determined to be present if both proximal segments of the anterior cerebral artery and the anterior communicating artery were visualized, or if filling and washout of the ipsilateral posterior cerebral artery could be seen. Collateral flow was determined to be inadequate if the anterior collateral system was incomplete, and if either the ipsilateral posterior communicating artery was absent or the posterior cerebral artery filled without washout. This information was compared with intraoperative electroencephalographic and shunting data.

RESULTS. Of 15 patients who had demonstrable collateral blood flow, 14 had stable electroencephalograms and did not require a shunt during surgery. In all 15 patients in whom no collateral flow to the ipsilateral hemisphere could be shown, electroencephalographic changes prompted placement of an intraluminal shunt.

CONCLUSION. We found that the angiographic determination of inadequate collateral cerebral circulation correlated strongly with the development of intraoperative ischemia. This implies that routine preoperative cerebral angiograms can be used to alert the surgeon to the potential need for shunt placement during carotid endarterectomy.

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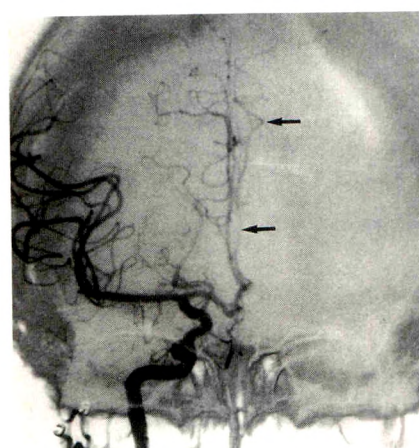
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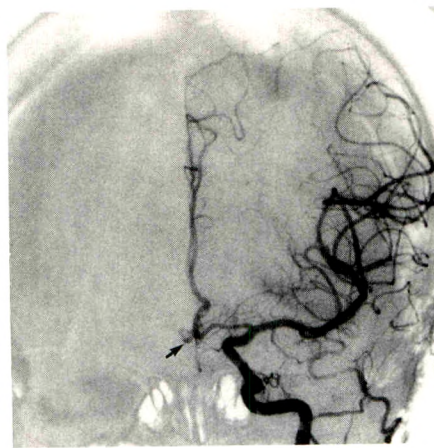
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In the past decade, carotid endarterectomy has become one of the most common vascular procedures performed in the United States. Moreover, recent evidence compiled by the National Institute of Neurological Diseases and Stroke with the North American Symptomatic Carotid Endarterectomy Trial has established the efficacy of carotid endarterectomy in the treatment of symptomatic high-grade stenosis [1], and it is likely that the number of these procedures will increase.

During carotid endarterectomy, the common carotid artery must be clamped to provide a bloodless surgical field. If collateral blood flow via the remaining cerebral vessels is insufficient to perfuse the ipsilateral cerebral hemisphere, an intraluminal shunt must be placed across the bifurcation. The placement of such a shunt is not a benign procedure, as it requires extra time and may result in intimal injury or embolization [2, 3]. Although several indicators of brain ischemia have been used intraoperatively [3, 4], electroencephalographic (EEG) monitoring is considered the gold standard for determining the need for placement of an intraluminal shunt [3]. Conventional EEG recordings have been shown to be highly accurate in the diagnosis of developing cerebral ischemia during carotid endarterectomy, correlating well with determinations of regional cerebral blood flow as well as the postoperative neurologic status of the patient [5-7]. However, the necessary equipment



A



B

Fig. 1.—Cerebral angiograms of patient with patent anterior communicating artery and A1 segments bilaterally.

A, Injection of right common carotid artery. Note flash filling of contralateral A2 segment (arrows).
B, Injection of left common carotid artery. Note flash filling of contralateral A1 segment (arrow). This patient did not require intraoperative shunting.

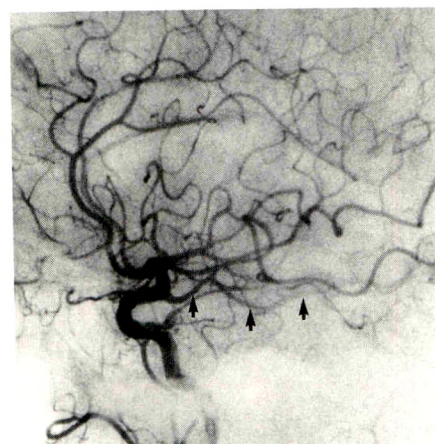


Fig. 2.—Cerebral angiogram after injection of common carotid artery shows flash filling of posterior cerebral artery via ipsilateral posterior communicating artery (arrows). This indicates communication with vertebrobasilar system, and this patient did not require shunting.

and trained personnel may not be readily available at all centers; in addition, EEG recordings may be altered by the effect of anesthetic agents. Thus, a preoperative assessment of the potential need for shunt placement may be of benefit to the surgeon. We retrospectively analyzed findings on preoperative cerebral angiograms in 30 patients to determine if we could predict the need for intraluminal shunting during carotid endarterectomy.

Materials and Methods

Thirty patients, 21 men and nine women 49–81 years old (mean age, 69 years), were chosen from a larger sample of 40 carotid endarterectomy patients selected retrospectively for an ongoing analysis of intraoperative EEG measurement techniques. By experimental design, this larger group was composed of equal numbers of patients who had received shunts during carotid endarterectomy because of intraoperative EEG changes suggesting ischemia and those who did not require shunt placement. These groups were matched for age and degree of stenosis of the ipsilateral and contralateral carotid arteries. Although all patients had bilateral carotid angiography before surgery, complete records of cerebral angiography were available in only 30 patients; this group consisted of 16 patients who required shunting intraoperatively and 14 who did not.

All patients had undergone carotid and cerebral angiography via a femoral artery approach as part of their preoperative assessment for suspected stenosis at the carotid bifurcation. Twenty-six patients were examined by means of intraarterial digital subtraction angiography, and in four patients the cut-film technique was used (Angioskop, Siemens Medical Systems, Iselin, NJ). In all cases, high-grade stenosis of at least one proximal internal carotid artery was shown, as defined by the presence of greater than 70% narrowing of the artery in the transverse dimension [1]. In all instances, both carotid arteries were injected, except for two cases in which occlusion had been previously determined angiographically. The average injection for the cerebral arteriogram was 10 ml of 60% Hypaque (meglumine

diatrizoate, Winthrop Pharmaceuticals, New York, NY) delivered at a rate of 8 ml/sec. Standard anteroposterior and lateral views of the cranial circulation were obtained. The common carotid artery on the opposite side was not compressed, and the vertebral arteries were not injected.

Angiograms were analyzed by a neuroradiologist who did not know the results of intraoperative monitoring; only the side of surgery was known. Collateral flow to the hemisphere ipsilateral to the carotid surgery was determined to be present if one of these two conditions was met: (1) communication with the opposite anterior/middle cerebral artery could be detected, that is, filling of both proximal anterior cerebral (A1) segments via either or both carotid injections and a demonstrably patent anterior communicating artery (Fig. 1), or (2) communication with the ipsilateral vertebrobasilar system could be shown, that is, filling of the ipsilateral posterior communicating artery with washout (flash filling) (Fig. 2). Lack of adequate collateral flow was judged to be present if either of the A1 segments or the anterior communicating artery could not be visualized with either carotid injection (Fig. 3) and if either the posterior communicating artery was absent (Fig. 4) or the posterior cerebral artery was of fetal origin (i.e., arising directly from the carotid siphon without communication with the basilar artery) (Fig. 5).

EEG monitoring was done with a Spectrum 32 EEG analyzer (Cadwell Laboratories, Kennewick, WA) with 19 referential and eight bipolar channels of conventional EEG (International 10–20 System). All EEG data were collected continuously throughout the surgery. Criteria for ischemia during clamping were based on a critical change in the EEG profile consisting of a 50% or greater decrease in amplitude in the alpha and beta frequency ranges or a 100% increase in activity in the delta frequency band in two or more adjacent channels [5–7].

In each case, the same technique of endarterectomy was used. The common carotid artery was dissected, and after vascular control was obtained with atraumatic arterial clamps placed below and above the bifurcation, a longitudinal arteriotomy was done through the extent of the lesion. If indicated by EEG changes, a polyethylene shunt was inserted across the bifurcation and secured with tourniquets. Endarterectomy of the internal carotid artery was then carried

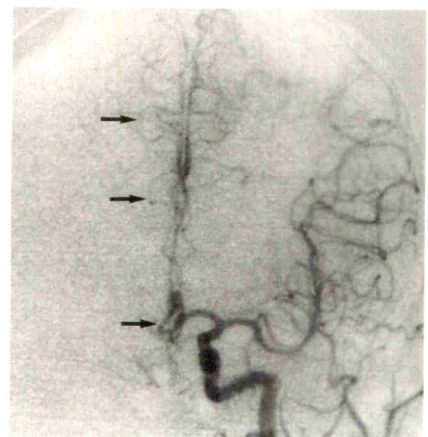
Fig. 3.—Cerebral angiogram of patient with absent right A1 segment.

A, Injection of right common carotid artery shows no opacification of right A1 segment or territory of right anterior cerebral artery.

B, Injection of left common carotid artery shows opacification of territory of right anterior cerebral artery (arrows) but no opacification of right A1 segment. This indicates absence of collateral flow across anterior portion of circle of Willis. This patient did not have a patent posterior communicating artery (not shown), and shunting was required.

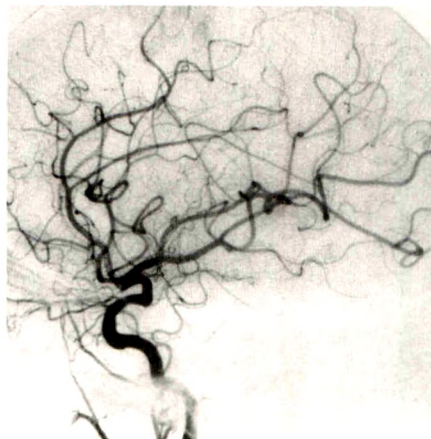


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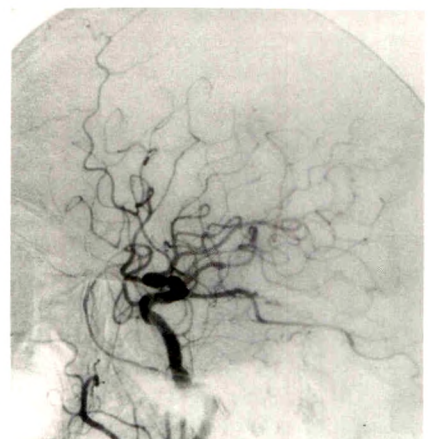
B

Fig. 4.—Cerebral angiogram after injection of common carotid artery shows no opacification of posterior communicating artery. This patient did not have a patent anterior collateral system (not shown), and shunting was required.



4

Fig. 5.—Cerebral angiogram after injection of common carotid artery shows fetal-type origin of posterior cerebral artery without washout. This indicates no communication with vertebrobasilar system. This patient did not have a patent anterior collateral system (not shown), and shunting was required.



5

out, with attention paid to the removal of loose intimal fragments. After this, the intraluminal shunt, if present, was removed, and the arteriotomy incision was closed with a fine continuous suture.

Cerebral angiographic results were analyzed with respect to the patency of potential collateral blood flow channels. These data were correlated with intraoperative EEG findings with a 2×2 χ^2 -test table by using the exact tests of Fisher, Irwin, and Yates [8].

Results

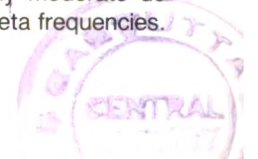
No significant difference was found between the shunted and nonshunted patient groups with respect to age (64.8 ± 7.3 years vs 69.6 ± 5.9 years, $p < .07$) or with respect to the degree of stenosis of the internal carotid artery that was operated on ($78.3 \pm 15.6\%$ vs $82.6 \pm 18.1\%$, $p < .50$) or of the contralateral internal carotid artery ($60.3 \pm 35.1\%$ vs $51.2 \pm 39.1\%$, $p < .52$). None of the patients in this study had evidence of significant intracranial vascular disease.

In seven (23%) of 30 patients, an A1 segment was not seen; in four patients, the A1 segment on the same side as the severe carotid stenosis was not opacified, and in three the contralateral A1 segment was not opacified. The anterior

communicating artery was not opacified from either carotid injection in five (17%) of 30 patients. The posterior communicating artery ipsilateral to the carotid artery that was operated on was not visualized in 11 (37%) of 30 patients, and the posterior cerebral artery arose directly from the internal carotid artery (fetal origin) in seven (23%) of 30 patients. The internal carotid artery contralateral to the surgically treated side was occluded in six cases.

In 15 patients (50%), no collateral flow to the hemisphere ipsilateral to the treated carotid artery could be shown via the anterior or posterior circulation. All of these patients had intraoperative EEG changes that indicated cerebral ischemia, prompting placement of an intraluminal shunt.

In 15 patients (50%), both A1 segments and the anterior communicating artery were patent or flash filling of the ipsilateral posterior communicating artery was shown. Of these patients, 14 had stable intraoperative EEG recordings and did not require a shunt during carotid endarterectomy. One patient had EEG changes that resulted in shunt placement; this patient, however, had the least prominent EEG abnormalities of all those who required shunts, with only moderate decreases in alpha and no significant drop in beta frequencies.



A statistically significant relationship was found between the presence or absence of angiographically demonstrable collateral blood flow and the development of intraoperative ischemia in the hemisphere ipsilateral to the internal carotid artery that was operated on ($p < .000001$).

Discussion

Several techniques have been used intraoperatively in the determination of cerebral perfusion during carotid occlusion for carotid endarterectomy, including measuring carotid stump pressure after clamping, monitoring the neurologic status of the awake patient, and most accurately, EEG analysis. However, each of these methods can be limited by errors in interpretation, the effects of anesthetics, or the availability of technical equipment or personnel [3, 4]. Furthermore, the use of intraluminal shunts during carotid endarterectomy lengthens the procedure and may obscure the operative field; it is also associated with risk of intimal injury [4]. The preoperative imaging of sources of collateral cerebral blood flow thus could be of benefit to the surgeon who wants to be selective in the use of intraluminal shunts. The results of this study indicate that standard preoperative cranial angiograms can be used with a high degree of accuracy to predict the development of ischemia during carotid endarterectomy. If either the anterior or the posterior portions of the circle of Willis can be shown to be intact, the patient most likely will have preserved flow to the hemisphere ipsilateral to the surgically treated carotid artery. However, if neither pathway is opacified by using routine angiographic techniques, the patient most likely will experience cerebral ischemia and require shunt placement.

The circle of Willis is the most important source of collateral blood supply in the human brain. The two A1 segments and the intervening anterior communicating artery provide collateral flow from the contralateral internal carotid artery, whereas the posterior communicating arteries provide communication with the vertebrobasilar system. A complete circle of Willis, however, is present in only 21% of persons [9]. Autopsy and surgical series [10] have shown that the posterior communicating artery is the most commonly hypoplastic portion of the circle, and this occurs in 22–32% of cases. The A1 segment is atretic on either side of the circle in approximately 25% of persons. In 15–22% of cases, the posterior cerebral artery has a fetal origin, and the anterior communicating artery is dysplastic in 9%. In addition, the percentage of patients with internal carotid stenosis in the general population who have contralateral occlusion of the internal carotid artery is approximately 9% [2]. Interestingly, the number of patients requiring shunting during carotid endarterectomy can be predicted by calculating the number of persons in whom both the anterior and posterior collateral systems are incomplete; from the above percentages, the number of patients expected to require shunts would be on the order of 20%, which agrees well with published rates of shunting during carotid endarterectomy [2, 11]. Potential collateral supply from sources other than the circle of Willis include contralateral external–ipsilat-

eral external carotid connections or leptomeningeal collateral vessels; such connections were not encountered in this study, however, and in general do not contribute significant collateral blood flow to the internal carotid circulation under circumstances of acute occlusion of the common carotid artery [12], as occurs when the common carotid artery is clamped during carotid endarterectomy. Interestingly, in our six cases of occlusion of the contralateral internal carotid artery, the development of ischemia of the hemisphere ipsilateral to the carotid endarterectomy correlated with the presence or absence of collateral flow via the posterior communicating artery. External-to-internal carotid anastomotic channels, if present on the occluded side, apparently did not provide sufficient blood flow via the anterior circulation to perfuse the opposite hemisphere adequately in these cases.

The findings in the present study are in agreement with the relative frequency of congenital variation of branches of the circle of Willis. The absolute rate of variations of the circle in our patients is greater than those determined by autopsy and surgical studies, however. This discrepancy is most likely related to our population of patients. Our patients were not randomly selected, but by experimental design were chosen so that they were roughly evenly divided into a group that required shunting during carotid endarterectomy and a group that did not. Hence, the proportion of patients in our series who had anomalies of the circle of Willis most likely was overrepresented relative to the general population. Also, acquired stenoses of intracerebral vessels, which are likely to be present in patients with carotid disease [4], probably contributed to the increased rate of incomplete circles in our study. More importantly, a diminutive vessel may not be visualized by angiographic means even though it may be anatomically patent. Specifically, cross compression was not done in any of our patients, so that a very small anterior communicating artery may not have been visualized owing to dilution of contrast material from unopacified blood. Similarly, a small posterior communicating artery may require a vertebral injection with compression of the ipsilateral carotid artery in order to be seen. However, our results suggest that the flow available through such a vessel would not be sufficient to supply the hemisphere after carotid occlusion. Thus, maneuvers such as cross compression, which may be injurious to a patient with carotid stenosis [10], do not appear to be necessary to determine the presence of adequate collateral flow during carotid endarterectomy.

In conclusion, our findings suggest that the angiographic determination of inadequate collateral cerebral circulation correlates strongly with the development of intraoperative ischemia and the need for carotid shunt placement during carotid endarterectomy. We should stress, however, that preoperative angiography should not replace the intraoperative EEG if it is available, as untoward events can occur even in the presence of a functioning shunt or demonstrably good collateral flow; emboli can propagate, shunts can malfunction, and even radiographically patent vessels can fail to deliver sufficient blood flow, as occurred in one of our patients. However, if EEG equipment is unavailable, the radiologist can predict that an ischemic episode might develop during cross clamp-

ing, and he or she can alert the surgeon to the potential need for an intraluminal shunt in such cases.

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Book Review

Radioisotopic Methods for Biological and Medical Research. By Herman W. Knoche. New York: Oxford University Press, 432 pp., 1991. \$42.50

Radioisotopic Methods for Biological and Medical Research is an excellent reference for those who are interested in learning the theory of radioisotopic methods in biology and chemistry. The text is designed as the formal basis for a lecture course or a self-study syllabus for the nascent research scientist.

In the section on preparing samples for liquid scintillation, the part on counting atypical emissions has interesting comments on bioluminescence and Cerenkov radiation, which are caused by different processes than those that occur in liquid scintillation. However, both phenomena are discussed because a scintillation instrument is used to assay both types of radiation. It is unusual to find a text that includes such detail to explain processes that are usually esoterically described as phenomena of radiation physics or as counting interference problems.

The book has an excellent description of macro- and microautoradiography that explains exposure technique, film, development, fluorography, electrophoresis gels, and autoradiographic interpretation. The author admits this section is an initial treatment of the topic and refers the reader to *Radionuclide Tracers* by M. F. L'Annunziata (1987) for a comprehensive description of autoradiographic studies, including the specific scientific methods used to perform these studies.

The title of the book is misleading, as most of the text is devoted to principles of radiation physics and concepts of radioactivity measurements. Readers who are looking for definitive nuclear medicine techniques that use radionuclides will be disappointed. Only autoradiographs, scintillation techniques, and radioimmunoassays are discussed to any appreciable extent.

The text is clearly organized and well-written. It begins with a short overview of regulations and responsibilities for users of radioactive materials as defined by the Nuclear Regulatory Commission (NRC), the International Commission on Radiological Protection, and the National Council on Radiation Protection and Measurements. The 11-page overview is followed by the main sections of the book. Part I

reviews nuclear physics, part II deals with the detection and measurement of radioactivity, part III is on biological effects of radiation and radiation safety, and part IV covers radiotracer methods. Two appendixes, one that lists physical constants and conversion factors and one that provides the answers to problems from the text conclude the book.

This text has more extensive coverage of solid and liquid scintillation counting methods than does the second edition of *Physics in Nuclear Medicine* by Sorenson and Phelps, which is oriented toward nuclear medicine imaging. A less intensive mathematical perspective makes *Radioisotopic Methods for Biological and Medical Research* easier to read than the Sorenson and Phelps text.

The regulations, responsibilities for users of radioactive materials, radiation protection standards, and practical aspects of radiation protection are cursorily discussed. No comprehensive description is given of the proper procedures for individual user compliance for a radiation safety program as required by the NRC.

The text is useful for gaining an understanding of the scientific approach to the general theory and use of radionuclides in biological and medical research. However, clinicians, residents, and students in training in nuclear medicine will not find much help in the text for learning the practical techniques necessary for clinical or research work in nuclear medicine unless they are interested in the areas mentioned in this review. *Radioisotopic Methods for Biological and Medical Research* provides an interesting review of topics that may not be well covered in a general nuclear medicine text and thus may be useful as a reference text for selected audiences.

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MR Imaging and HMPAO Scintigraphy in Conjunction with Balloon Test Occlusion: Value in Predicting Sequelae After Permanent Carotid Occlusion

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OBJECTIVE. Permanent occlusion of the internal carotid artery may be required for en bloc resection of a neck tumor or to treat certain aneurysms. The risk of ischemic infarct is usually assessed with carotid balloon test occlusion and concurrent distal arterial pressure measurement. However, up to 20% of patients who tolerate the test occlusion have delayed neurologic sequelae. We propose enhanced MR imaging and hexamethylpropyleneamine oxime (HMPAO) scintigraphy to detect subclinical signs of ischemia and hypoperfusion as adjuncts to the balloon test occlusion to identify patients at risk for delayed sequelae.

SUBJECTS AND METHODS. We prospectively examined 12 patients referred for balloon test occlusion of the carotid artery. Serial measurements of distal occluded internal carotid pressure were recorded. ^{99m}Tc-HMPAO was injected IV after 2 min of asymptomatic test occlusion, and single-photon emission computed tomographic (SPECT) data acquisition was done 1–6 hr later. Contrast-enhanced MR imaging was performed 1–8 hr after completion of the 30-min test occlusion. Signs of decreased perfusion or ischemia on these tests were compared with the mean distal arterial pressure and neurologic status of the patient during test occlusion.

RESULTS. Seven (58%) of 12 patients had abnormal findings on HMPAO scintigraphy or contrast-enhanced MR imaging. Only one patient had neurologic deficits that corresponded to abnormal MR enhancement. The other 11 patients (92%) remained asymptomatic during the 30-min test occlusion. Of these 11 asymptomatic patients, five (45%) had areas of decreased perfusion on scintigraphy and three (27%) had abnormal MR contrast enhancement suggesting residual focal ischemia as a result of the test occlusion. Mean arterial pressures in the distal occluded artery did not correlate well with the imaging results.

CONCLUSION. HMPAO scintigraphy can show clinically silent areas of decreased perfusion, while enhanced MR shows signs of acute ischemia (i.e., significant hypoperfusion) associated with asymptomatic balloon test occlusion. Theoretically, such patients would be at increased risk for permanent sequelae after permanent carotid occlusion.

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Permanent occlusion of the internal carotid artery may be required to resect neck tumors that encase or are adherent to the carotid artery. This is also a treatment option for some aneurysms. Determining whether collateral cerebral blood flow is sufficient for the patient to tolerate sacrifice of this artery typically depends on preoperative balloon test occlusion with tailored neurologic evaluation and measurement of distal arterial pressure during the procedure. However, up to 20% of patients have delayed neurologic sequelae after permanent occlusion despite tolerating a 15- to 30-min test occlusion without symptoms [1, 2].

We assessed contrast-enhanced MR imaging and ^{99m}Tc-hexamethylpropyleneamine oxime (HMPAO) scintigraphy for the detection of subtle subclinical signs of brain ischemia or perfusion deficit resulting from balloon test occlusion.

Subjects and Methods

Twelve patients (four women and eight men 21–79 years old) were included in this prospective study. The group included 11 patients with tumors in the neck or skull base (seven squamous cell carcinoma, four other) that necessitated resection and preoperative balloon test occlusion of the carotid artery. One patient required permanent balloon occlusion of the internal carotid artery to treat a cavernous aneurysm. All patients had contrast-enhanced MR imaging after balloon test occlusion. Eleven patients were evaluated with HMPAO scintigraphy as well.

Balloon Test Occlusion

The test occlusion procedure began with diagnostic cerebral angiography performed via the femoral artery to evaluate for vascular abnormalities caused by tumor or atherosclerosis, as well as collateral flow across the circle of Willis. Then, a 7-French double-lumen occlusive balloon (diameter, 11.5 mm) catheter (Medi-tech, Watertown, MA) was passed into the common carotid artery. After systemic anticoagulation was started with 5000 units of heparin administered IV, the balloon was positioned in the internal carotid artery approximately at the level of C2. In one patient, test occlusion of the common carotid artery was performed because of severe atherosclerotic narrowing of the internal carotid artery. A baseline measurement of blood pressure in the distal internal carotid artery was obtained before balloon inflation.

Before the balloon test occlusion, a baseline neurologic examination was performed to evaluate motor, sensory, and higher cortical functions in both hemispheres. After the balloon was inflated, cessation of antegrade flow was confirmed by stasis of contrast material above the balloon. Tailored neurologic testing of the unsedated patient was done at 10-min intervals during the 30-min test occlusion.

Electroencephalographic (EEG) monitoring was used with only one patient. EEG changes or neurologic symptoms were criteria for immediate termination of the balloon test occlusion. If the patient tolerated 30 min of internal carotid artery test occlusion, the balloon was deflated and removed from the internal carotid artery. Systemic heparinization was reversed with protamine sulfate before the catheter was removed from the femoral artery.

Mean Distal Carotid Arterial Pressure

Five pressure measurements were made in the distal carotid artery: before and immediately after test occlusion and 10, 20, and 30 min after occlusion. A lowest recorded mean distal arterial pressure (MDAP) of 50 mm Hg or higher in an asymptomatic patient was considered acceptable. Values of 49 mm Hg or less are thought to be associated with collateral flow insufficient to risk permanent occlusion [3].

^{99m}Tc-HMPAO Scintigraphy

If no neurologic signs of acute brain ischemia developed after 2 min of balloon test occlusion, 20 mCi (740 MBq) of ^{99m}Tc-HMPAO was injected IV. Single-photon emission computed tomographic (SPECT) images reflecting regional cerebral blood flow during this period were recorded 1–6 hr later. Imaging was performed with a triple-headed camera (Triad 88, Trionix, Twinsburg, OH) equipped with a high-resolution collimator. Data were acquired for 20 min and reconstructed by standard back-projection methods. Coronal, axial, and sagittal images were generated in all cases and reviewed by one nuclear medicine physician and one neuroradiologist who did not know the balloon test occlusion site or neurologic status during the balloon test occlusion. Focal regions of low or absent radiotracer

activity on visual inspection were interpreted as areas of low or absent perfusion during the initial 2 min of test occlusion. Scintigrams with abnormal findings were repeated after 24 hr to evaluate the reversibility of the focal defect.

Contrast-Enhanced MR Imaging

Contrast-enhanced MR imaging was performed 1–8 hr after balloon test occlusion of the internal carotid artery. All examinations were done with either a 0.5-T (Picker International, Highland Heights, OH) or a 1.5-T (General Electric, Milwaukee, WI) superconductive scanner. At least one T1-weighted (350–583/20 [TR/TE]) and one T2-weighted (2000–2350/90–100) unenhanced spin-echo pulse sequence were obtained, as were T1-weighted images immediately after IV injection of 0.1 mmol/kg of gadopentetate dimeglumine with the same image parameters used for unenhanced studies. All examinations were reviewed prospectively by two neuroradiologists who did not know the balloon test occlusion site or the clinical findings. Special attention was given to abnormal signal intensity, mass effect on the unenhanced examination, and abnormal enhancement (parenchymal and/or vascular) on the enhanced images.

Results

Imaging test results were significantly different from those of the balloon test occlusion. Although only one patient was symptomatic during test occlusion, 58% (7/12) of the patients had abnormal findings on contrast-enhanced MR and/or scintigraphy. This included 55% (6/11) of the asymptomatic patients. Five of 12 patients had no evidence of ischemia on either the test occlusion, MR, or scintigraphy.

Shunting or preservation of the internal carotid artery was a surgical priority if feasible during surgery, and this was possible in most of our patients. A total of three patients underwent permanent occlusion of the internal carotid artery, all without ill effect. Only one of these patients had abnormal findings on MR. All three scintigrams showed normal symmetry.

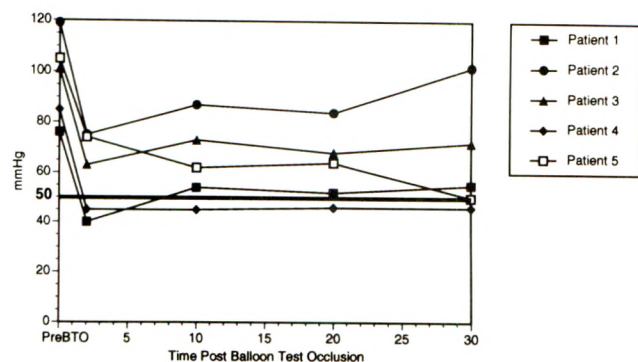
Mean Arterial Pressure in Distal Occluded Artery

With 50 mm Hg as a threshold, postocclusive MDAP did not correlate well with clinical and imaging results in our limited group of patients. Plots of MDAP in patients with normal findings on imaging studies do not differ significantly from those of patients with abnormal findings (Fig. 1).

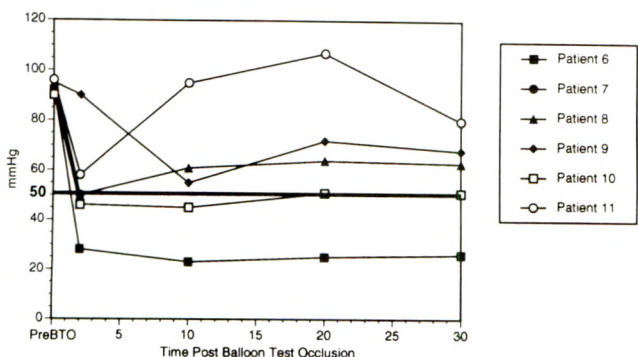
In the six asymptomatic patients with signs of ischemia on imaging studies, four (67%) had an MDAP of 50 mm Hg or greater. Despite signs of low perfusion and ischemia, as shown by the scintigraphic and MR studies, the patient with the lowest MDAP (23 mm Hg) was asymptomatic throughout the entire 30-min balloon test occlusion.

^{99m}Tc-HMPAO: Evaluation of Cerebral Perfusion During Balloon Test Occlusion

Five of the 11 asymptomatic patients had focal HMPAO defects in the distribution of the middle cerebral artery tributary to the test occluded artery. Two of these patients also had abnormal MR enhancement ipsilaterally (Fig. 2). In the other three patients, abnormal scintigrams exhibited de-



A



B

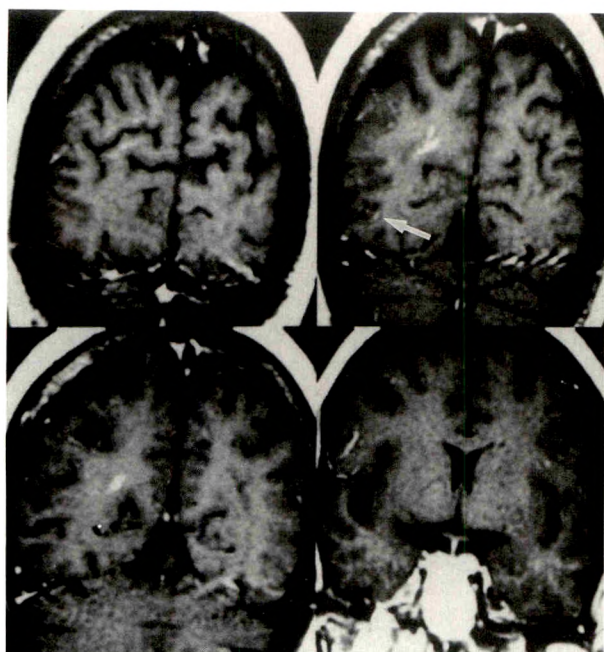
Fig. 1.—A and B, Mean arterial pressures in distal occluded carotid artery before (preBTO) and during balloon test occlusion in patients with normal (A) and abnormal (B) findings on HMPAO scintigrams and MR studies. Initial drop in distal arterial pressure with gradual increase over time in several patients suggests collateral flow takes time to develop.

creased ipsilateral radiotracer uptake with no evidence of ischemia on MR examinations performed 3–6 hr after balloon test occlusion (Fig. 3). All asymmetric scintigrams were repeated 24 hr later and showed return of the normal symmetric pattern. Only one patient with abnormal MR findings had normal scintigraphic findings.

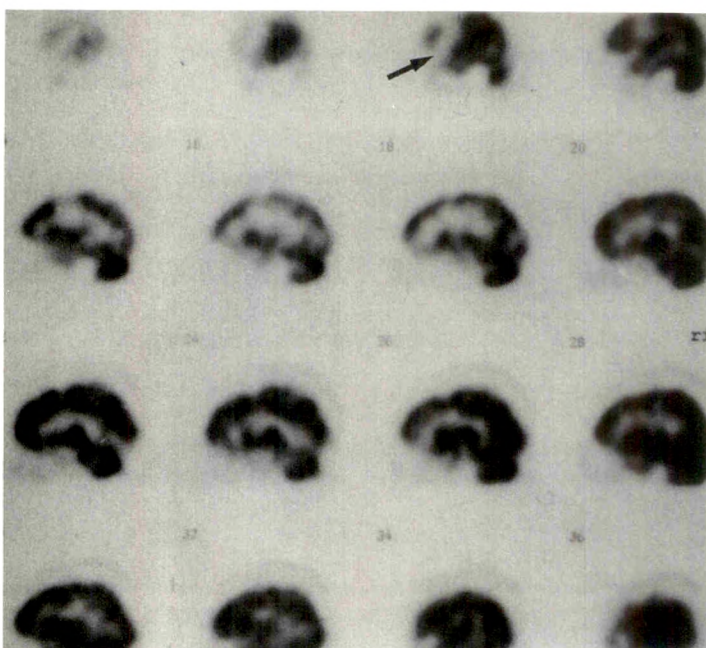
Contrast-Enhanced MR Imaging: Evaluation of Residual Ischemia After Balloon Test Occlusion

Of the 11 asymptomatic patients, three had signs of ischemia on contrast-enhanced MR. Initial MR studies showed no abnormalities on T1-weighted images, but variable degrees of parenchymal enhancement were present in the ipsilateral middle cerebral artery and watershed regions (Fig. 2). Abnormal vascular enhancement was not seen in the major vessels of the sylvian fissure, but it was present in a few distal cortical branches in two patients. No evidence of abnormal signal was seen on the T2-weighted study in any of these three patients with abnormal enhancement. Two patients had a follow-up contrast-enhanced MR examination 1 week later that showed a significant decrease in the previously noted parenchymal enhancement, suggesting transient ischemia. Results of the T2-weighted study remained normal. One patient with normal findings on scintigraphy had abnormal parenchymal enhancement in the anterior/middle cerebral artery watershed region as well as in a few cortical vessels. This enhancement resolved despite permanent balloon occlusion of the artery, and the patient remained asymptomatic.

In the only patient who had acute neurologic symptoms (facial droop, right hemiparesis, and aphasia) during the bal-



A



B

Fig. 2.—54-year-old woman with squamous cell carcinoma adjacent to right internal carotid artery was asymptomatic during test occlusion with a mean distal arterial pressure of 50 mm Hg.

A, Coronal contrast-enhanced T1-weighted (350/20) spin-echo MR images obtained 7.5 hr after balloon test occlusion of right internal carotid artery. Abnormal vascular enhancement is seen in cortical vessels (arrow) on right side and in parenchymal white matter. Follow-up study 8 days later showed minimal residual enhancement. No abnormality was seen on T2-weighted images.

B, Sagittal SPECT ^{99m}Tc -HMPAO scintigram obtained 2 hr after radionuclide injection shows a small focal defect (arrow) on right side corresponding to abnormal MR enhancement in A. Follow-up study 24 hr later showed normal symmetry, suggesting that the focal defect seen previously reflected perfusion changes caused by balloon test occlusion. During tumor resection, careful dissection allowed preservation of right internal carotid artery.

loon test occlusion, diffuse parenchymal enhancement in the ipsilateral parietal and temporal lobes in the distribution of the middle cerebral artery was seen 2 hr later (Fig. 4). Unenhanced MR images, including T2-weighted images, showed no signal changes. The 24-hr follow-up study showed mild cerebral edema consisting of increased signal in the middle/posterior

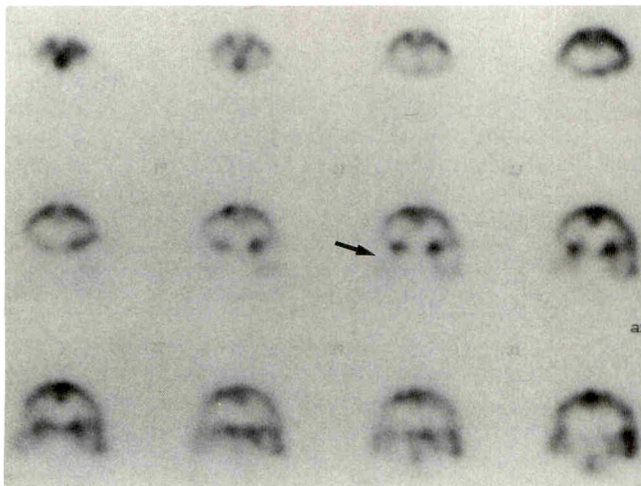


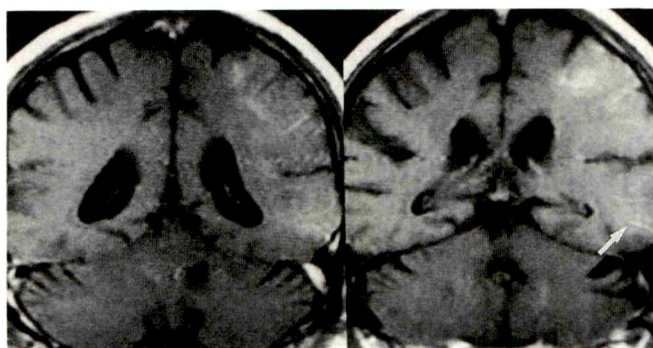
Fig. 3.—66-year-old woman with squamous cell carcinoma involving right carotid sheath was asymptomatic during balloon test occlusion. Coronal SPECT ^{99m}Tc -HMPAO scintigram after balloon test occlusion of right internal carotid artery shows a small focal defect (arrow) in right temporal lobe laterally. Results of MR examination were normal, as were results of follow-up scintigraphy 24 hr later. Carotid bypass was performed during surgical resection of tumor.

cerebral artery watershed region on T2-weighted images, without abnormal enhancement. Significant improvement was seen on the 48-hr and 1-week follow-up studies, and complete resolution occurred at 1 month. The patient experienced complete relief of symptoms by 48 hr after test occlusion. Because of the rapid onset of symptoms, requiring immediate termination of the test occlusion procedure, ^{99m}Tc -HMPAO was not administered.

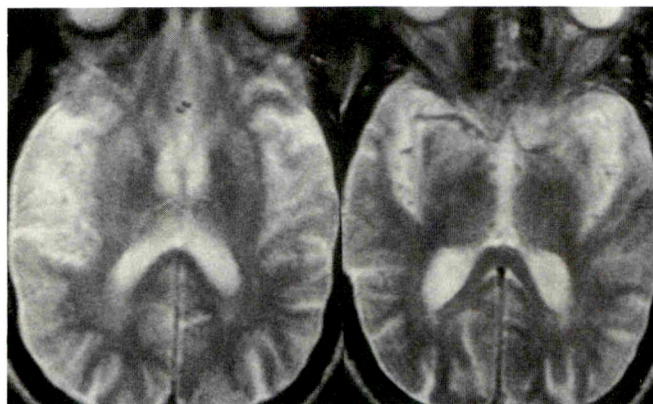
Discussion

Traditionally, back-pressure measurement [4], EEG monitoring [5], and xenon CT [6] during test occlusion have been used as adjuncts to detect signs of ischemia after temporary internal carotid artery occlusion. Recently, HMPAO scintigraphy has been reported as a method to detect focal hypoperfusion during test occlusion [7–9]. We propose contrast-enhanced MR imaging, in addition, to detect the sequelae of significant focal decreased perfusion (i.e., ischemia).

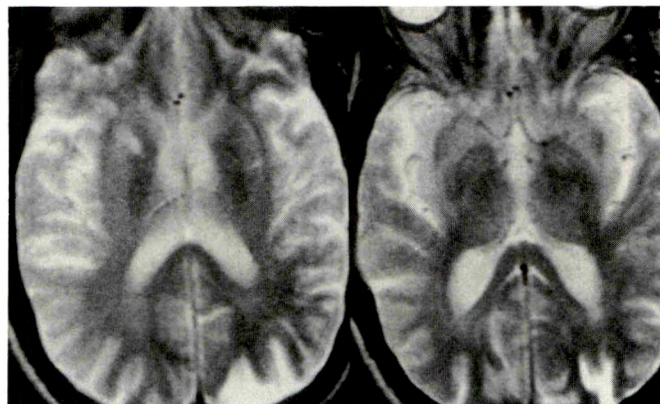
Measurement of pressure in the distal occluded artery has long been the main tool to assess collateral flow during balloon test occlusion. However, there is no consensus in the literature as to what constitutes a safe lower limit of MDAP. Theoretically, lower distal pressure should correlate with low collateral flow and increased risk of ischemia infarct. Moore and Hall [10] initially described this technique and observed loss of consciousness caused by cross clamping of the carotid artery during endarterectomy in five of 36 patients. All five of



A



B



C

Fig. 4.—In this patient, acute neurologic symptoms caused by test balloon occlusion of left common carotid artery completely resolved after 48 hr.

A, Coronal contrast-enhanced T1-weighted (350/20) spin-echo MR images obtained 2 hr after balloon test occlusion. Prominent parenchymal enhancement is present on left side along with enhancement of a few cortical vessels (arrow). This enhancement had markedly decreased after 24 hr.

B and C, Axial T2-weighted (2000/90) MR images initially showed no abnormal signal (B); however, abnormal signal developed in left occipital lobe after 24 hr (C). This also was completely resolved by 1 month after test occlusion.

these patients had an MDAP of 22 mm Hg or less. Thus, they concluded that an MDAP of 25 mm Hg or more correlated well with tolerance of temporary carotid occlusion.

Later, Hays et al. [3] reported 50 mm Hg as the lower limit of safe MDAP in their series of 297 operations. Neurologic deficits were observed in 50% of patients with an MDAP of less than 50 mm Hg in which shunting during endarterectomy was not used. Some surgeons recommend even higher minimum back pressures, in the range of 60–70 mm Hg, below which protective shunts should be used during endarterectomy [11]. Kelly et al. [12] reported that 77% of their patients requiring shunts, by EEG criteria, during carotid endarterectomy for vertebrobasilar insufficiency had back pressures of greater than 50 mm Hg. This suggests a higher MDAP may be required in situations less favorable for collateral flow, as in concomitant vertebrobasilar stenosis. No clear conclusion about the reliability of absolute MDAP can be made from our few patients. However, pressures did not appear to correlate well with the imaging studies (Fig. 1). One fourth of our patients with an MDAP value of 50 mm Hg or more had an abnormal MR and/or scintigram.

EEG slowing of the normal fast activity in the ipsilateral distribution of the occluded carotid artery is generally interpreted as brain ischemia [13]. However, Beebe et al. [14] found a poor correlation between EEG changes and distal occluded carotid pressures. Scheyvaerts and Limet [5] found no correlation between EEG changes and clinically detectable ischemic compromise in 59 carotid endarterectomy patients. In our only symptomatic patient, EEG changes were simultaneous with the development of symptoms. However, the EEG normalized immediately after deflation of the balloon, whereas symptoms persisted. In our experience, symptoms develop simultaneously with EEG changes, making the EEG of limited usefulness. The lead wires are also somewhat inconvenient. For these reasons, we no longer use EEG routinely during balloon test occlusion at our institution.

Xenon CT cerebral blood flow mapping can be used to detect focal areas of inadequate perfusion, defined as less than 30 ml/100 g per minute [6]. This is a promising technique that appears to measure directly the variable of interest (i.e., perfusion). However, this technology is not available at all centers. Also, the patient must be transported to the CT scanner with the balloon catheter positioned in the internal carotid artery. In contrast, MR imaging and SPECT scintigraphy are widely available techniques that provide higher resolution images. Both can be done after balloon test occlusion is completed and the catheter has been removed.

HMPAO scintigraphy reflects blood flow during the first few minutes of test occlusion. Following IV injection of HMPAO, 3.5–7% localizes in the brain within the first 2 min, and thereafter brain concentrations are stable bound to glutathione for several hours [15]. In previous studies that used HMPAO scintigraphy as an adjunct to test occlusion, nine (27%) of 33 asymptomatic patients had abnormal, asymmetric scintigrams [7–9]. Our results were somewhat higher, with 45% of asymptomatic patients having asymmetric scintigrams. This difference may reflect the timing of injection. In the cited studies, the radiotracer was injected 5–15 min after carotid occlusion. Analysis of our graphs of MDAP vs time

after occlusion shows an initial precipitous drop in pressure with gradual improvement in six of 11 patients (Fig. 1). This suggests it may take time for collateral perfusion to develop. It also suggests later injection may be a better reflection of collateral flow. Optimal injection time requires further study.

Recent reports have shown contrast-enhanced MR to be sensitive in showing early and subtle signs of ischemia [16, 17]. In the setting of carotid test occlusion, abnormal contrast enhancement on MR is theoretically most indicative of a patient at risk for ischemic infarct. The one patient who was symptomatic experienced complete resolution of symptoms within 48 hr, corresponding to the resolution of abnormal parenchymal enhancement, although the T2 abnormality took 28 days to normalize. The other three patients with abnormal MR studies presumably had subclinical ischemia or significant ischemia in a "silent" area of the brain, which was a transient phenomenon during balloon test occlusion. However, these areas of ischemia could have persisted to develop into an infarct, or extended into nonsilent areas of the brain, if a permanent balloon occlusion or carotid ligation had been performed. Because the abnormal parenchymal enhancement resolved eventually and no T2 abnormalities developed in the asymptomatic patients, MR findings 2–8 hr after balloon test occlusion most likely represent residual resolving ischemic changes occurring during the 30-min balloon test occlusion.

The advantages of enhanced MR imaging include the ability to perform the examination when convenient after balloon test occlusion, no need for injection during the angiographic procedure, and results that reflect the temporal ischemic changes during the entire balloon test occlusion. One disadvantage may result from the rapid resolution of some transient ischemic changes occurring after balloon test occlusion. With an average 4-hr delay between balloon test occlusion and MR examination in our cases, ischemic changes may be diminished significantly and therefore missed at the time of scanning. However, those changes that disappear within 1 hr may not be as significant as those that persist for hours after balloon test occlusion.

The three patients with an abnormal scintigram and a normal MR study may reflect the fact that the examinations serve to evaluate two different variables. The HMPAO uptake reflects blood flow during the first few minutes of the test occlusion, whereas the MR study reveals residual signs of ischemia resulting from transient decreased blood flow hours after the balloon test occlusion. Focal decreased flow on the scintigram may not be low enough to cause ischemia, and thus the appearance on MR will be normal.

One patient with a normal SPECT examination did have evidence of ischemia on contrast-enhanced MR. This may be because the HMPAO study only reflects the blood flow at a single point in the balloon test occlusion rather than the entire 30 min during which undetected low flow in a focal area may have caused ischemia. The fact that abnormal enhancement on the MR examination reflects some type of ischemic damage may be more clinically significant than slight blood flow asymmetry on the HMPAO scintigram. However, despite the abnormal MR enhancement, this patient did well after permanent balloon occlusion of the artery. There was no evidence of ischemia on the contrast-enhanced MR examination

done after permanent occlusion, suggesting collateral circulation had improved. Further study is needed.

In conclusion, we have shown that ^{99m}Tc -HMPAO SPECT does show clinically silent areas of low perfusion, and contrast-enhanced MR imaging can reveal cerebral ischemia despite an asymptomatic internal carotid artery on balloon test occlusion study. Patients with these imaging findings may be at increased risk for delayed neurologic sequelae after permanent occlusion of the carotid artery. However, confirmation with a larger series that includes patients whose carotid arteries could not be salvaged despite indeterminate balloon test occlusion and/or abnormal imaging study results is needed. The limited number of patients and the lack of an accurate scientifically established criterion for comparison make it difficult to judge the significance of our findings or which technique would be most useful.

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Pictorial Essay

MR Imaging of Clival and Paraclival Lesions

Gregory Chaljub,¹ Robert Van Fleet, Faustino C. Guinto, Jr., Wayne N. Crow, Lisa Martinez, and Rajendra Kumar

A wide spectrum of diseases involve the clivus and paraclival structures. Primary neoplasms, metastatic tumors, and inflammatory, vascular, and hematopoietic disorders are the most common abnormalities to arise from or directly involve the clivus. MR imaging exquisitely shows and helps characterize the diseases that affect this area. Sagittal and coronal MR imaging allows precise localization and evaluation of the signal characteristics of a mass, enabling a more specific diagnosis. The multiplanar capabilities of MR imaging provide superb visualization of the adjacent cranial nerves and vascular structures, aiding in surgical planning and radiation therapy. In this pictorial essay, the MR imaging, CT, and conventional radiographic findings of various clival and paraclival lesions are illustrated.

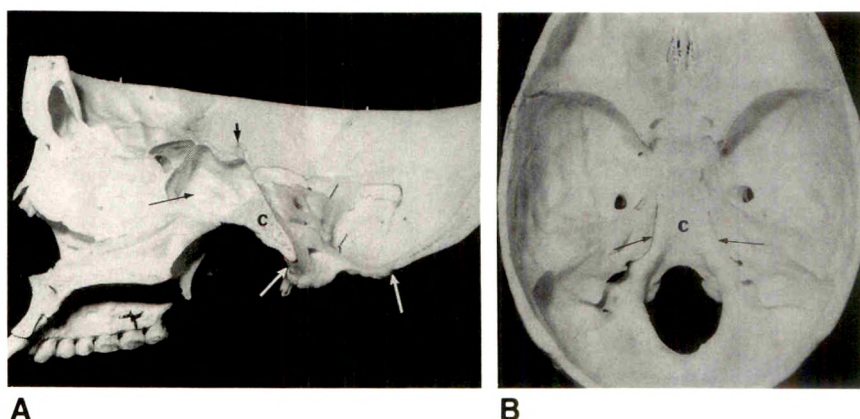
Anatomy and Embryology

The clivus is that part of the skull base situated between the foramen magnum and dorsum sellae (Fig. 1A). It is bounded laterally by the petrooccipital fissure and the synchondrosis between the basioccipital and exoccipital bones. The petrooccipital fissure begins near the cavernous sinus and extends inferiorly to the jugular foramen (Fig. 1B). The synchondrosis between the basioccipital and exoccipital bones fuses at 3–4 years of age when it forms the lateral margin of the clivus at the foramen magnum. The anterior margin of the clivus abuts the sphenoidal sinus, whereas the

Fig. 1.—Anatomic sections of a skull displaying clivus.

A, Sagittal section shows clivus (c), sphenoidal sinus (long black arrow), dorsum sellae (short black arrow), and foramen magnum (white arrows).

B, Axial section shows clivus (c) and petrooccipital fissures (arrows).



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inferior margin represents the nasopharyngeal surface of the base of the skull. The posterior surface is usually concave or flat and is the anterior surface of the prepontine and premedullary cisterns.

The clivus is originally a cartilaginous structure that, along with a remnant of the notochord, ossifies to form the basisphenoid and the basiocciput. The synchondrosis between these two bones (sphenoccipital synchondrosis) is completely fused by age 25 (Fig. 2B).

MR Appearance

Normal

The clivus is best seen on the midsagittal view and resembles a triangle whose base passes through the dorsum sellae and whose apex is at the anterior margin of the foramen

magnum. Normally, a fat pad is located anteroinferior to the tip of the clivus just above the odontoid bone (Fig. 2A). MR imaging, because of its multiplanar capabilities and lack of the beam-hardening artifact seen on CT, provides better anatomic detail for the clivus and posterior fossa.

Compact cortical bone forms the anterior and the posterior boundaries of the clivus and is depicted as a black line on both T1- and T2-weighted images (Fig. 3). The central portion of the clivus is composed of cancellous bone. MR signal characteristics of the normal clivus depend on the amount and nature of the marrow elements forming the cancellous bone. Red marrow (hematopoietic tissue) predominates up to approximately 3 years of age and results in low signal on T1-weighted images. Fatty metamorphosis of the marrow slowly progresses after 3 years of age and is usually complete by 10 years of age. The fatty marrow produces high signal

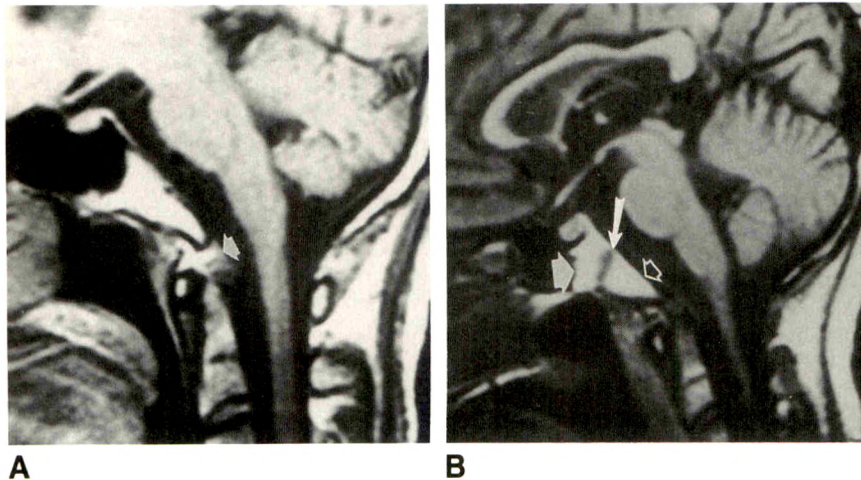


Fig. 2.—Normal clivus in an adult and child.

A, Sagittal T1-weighted image of a 46-year-old man shows normal high-intensity signal representing fatty marrow in clivus. Note normal infraclival fat just superior to odontoid bone (arrow).

B, MR image of clivus in a 12-year-old patient. Signal characteristics are similar to those in adults except for sphenoccipital synchondrosis (long solid arrow). Note basisphenoid (short solid arrow) and basiocciput (open arrow).

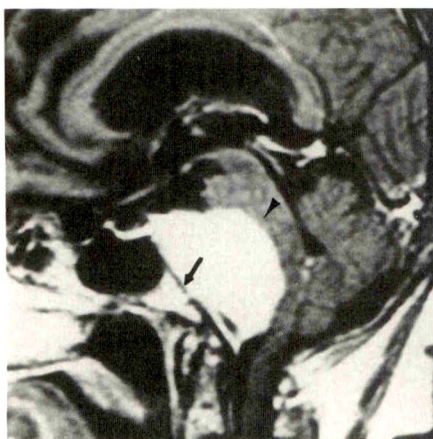


Fig. 3.—Clival meningioma in a 59-year-old woman. Contrast-enhanced midsagittal MR image reveals extraaxial mass abutting clivus (arrow). Intense enhancement is characteristic of meningioma. Note compression of pons (arrowhead) by convex tumor.

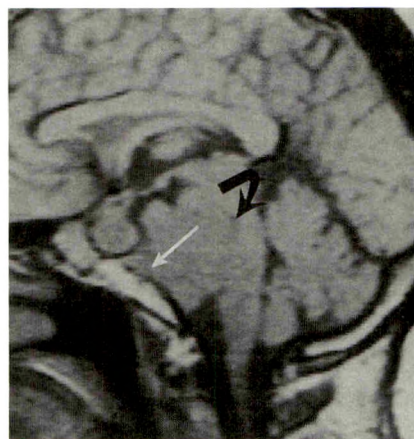


Fig. 4.—Parasellar meningioma in a 48-year-old woman. Midsagittal T1-weighted MR image shows isointense mass invading clivus (straight arrow) and prepontine cistern (curved arrow).

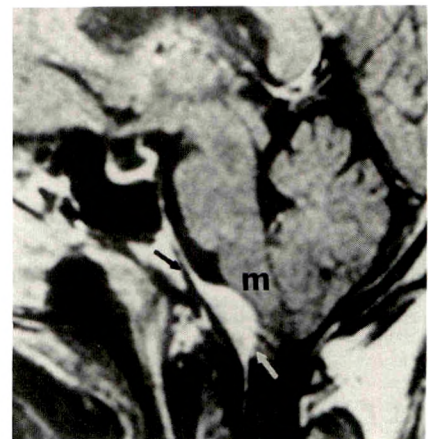


Fig. 5.—Foramen magnum meningioma in a 50-year-old woman. Midline sagittal contrast-enhanced T1-weighted MR image exquisitely displays enhancing foramen magnum meningioma (white arrow) impinging on medulla (m). Note posterior aspect of cortical bone of clivus (black arrow).

intensity on T1-weighted images and relatively decreased signal on T2-weighted images.

Abnormal

The clival abnormalities shown on MR images, CT scans, and plain radiographs in this essay include primary neoplasms (Figs. 3–11), secondary and paracaval tumors (Figs. 12–15), infectious and inflammatory processes (Figs. 16–18), vascular abnormalities (Fig. 19), hematopoietic disorders (Fig. 20), and miscellaneous abnormalities (Figs. 21 and 22).

The MR pulse sequences used most often were sagittal T1-weighted (500–600/20–25/2 [TR/TE/excitations]) spin-

echo images with a 6-mm slice thickness obtained on a 0.6-T unit (Health Images High Caliber, Atlanta, GA). Also used were axial T1-weighted (500–600/20–25/2) and T2-weighted (2000/60–120/2) spin-echo images of the brain and clivus with 8-mm-thick slices. In most patients, contrast-enhanced images were obtained in all three planes after administration of gadopentetate dimeglumine.

Most abnormalities exhibit low signal on T1-weighted images and high signal on T2-weighted images, indicative of replacement of the normal fatty marrow. Kimura et al. [2] recently published a retrospective review of approximately 500 patients in which they compared the signal characteristics of the normal and abnormal clivus vs the pons on sagittal T1-

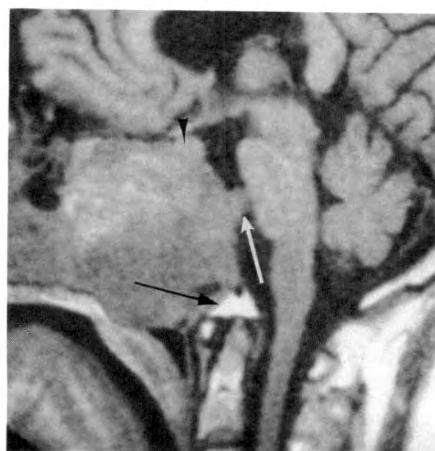


Fig. 6.—Chordoma involving clivus in a 77-year-old man. Midline sagittal T1-weighted MR image reveals large heterogeneous mass destroying clivus and extending into nasopharynx, sella (arrowhead), and preoptine cistern (white arrow). Note infracaval fat (black arrow). Chordomas are neoplasms that arise from remnants of notochord. Chordomas of cranium account for 35% of all such tumors; those of sacrum, 50%; and those of cervical, thoracic, or lumbar spine, 15%.

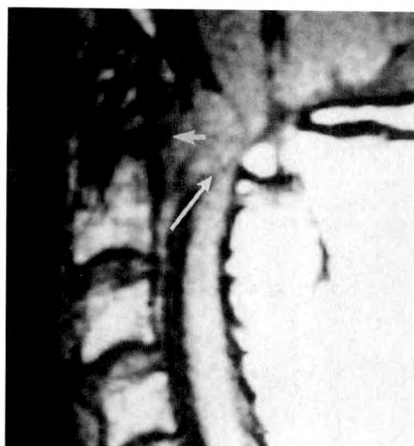


Fig. 7.—Odontoid chordoma in a 59-year-old man. Midline sagittal T1-weighted MR image shows an infracaval mass arising from odontoid process. (Short arrow shows posterior aspect of lesion against odontoid process and long arrow shows compression of anterior spinal canal and cord). Surgical pathway for exposing inferior clival and C1 lesions is via transoral-transpharyngeal approach.

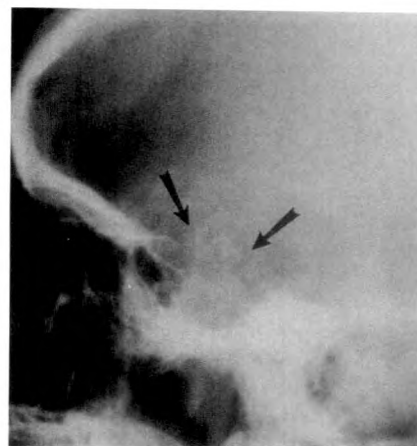


Fig. 8.—Enondroma in a 16-year-old patient. Lateral radiograph of skull shows large mass (arrows) expanding and destroying clivus in patient with Maffucci's syndrome. Maffucci's syndrome usually consists of multiple enondromas with soft-tissue hemangiomas in an asymmetric unilateral distribution.

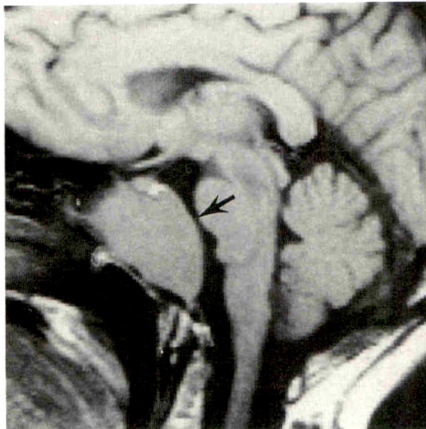


A



B

Fig. 9.—Osteochondroma in a 62-year-old man. A, Midline sagittal T1-weighted MR image shows clival expansion and replacement of normal marrow by calcification, which accounts for low signal. Note pons-tumor interface (long arrow) and bowing of optic chiasm superiorly (short arrow). B, Axial proton density-weighted MR image (2000/28) shows effacement and involvement of left cavernous carotid artery (solid arrow). Note normal flow void of right cavernous carotid artery (open arrow). A CT scan revealed a large calcified mass arising from clivus.



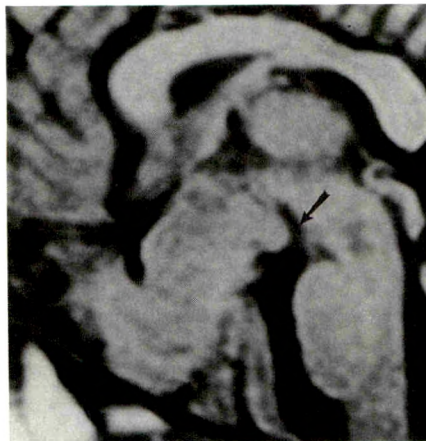
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11

Fig. 10.—Plasmacytoma in a 68-year-old woman. Midline sagittal T1-weighted MR image shows expansile lesion along with homogeneous intermediate signal characteristic of plasmacytoma. Note narrowing of preoptine cistern (arrow).

Fig. 11.—Chloroma in a 50-year-old woman with chronic myelogenous leukemia. Midline sagittal T1-weighted MR image reveals hypointense mass (black arrow) extending into base of clivus. Note sphenoidal sinus (white arrow). (Reprinted from Freedy and Miller [1].)



A



B

Fig. 12.—Pituitary prolactinoma in a 29-year-old patient.

A, Midline sagittal T1-weighted MR image shows large sellar-suprasellar mass eroding into sphenoidal sinus and clivus. Epicenter is in region of pituitary fossa. Note involvement of interpeduncular cistern (arrow).

B, Contrast-enhanced coronal MR image shows marked cavernous sinus involvement (arrows) with encasement of cavernous carotid arteries. Prolactin level was greater than 750 ng/l.

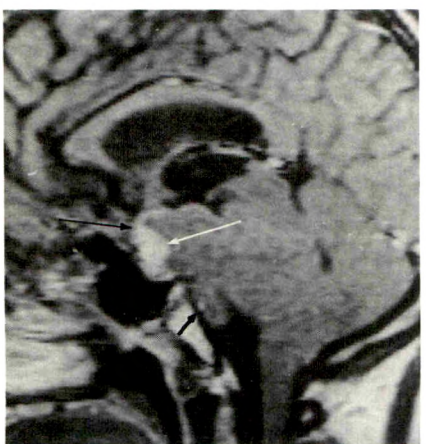


Fig. 13.—Craniopharyngioma in a 24-year-old man. Contrast-enhanced sagittal MR image shows heterogeneously enhancing mass arising from sellar-suprasellar region and extending posteriorly along dorsal clivus (short black arrow). Note erosion of dorsum sellae (long black arrow) and cystic component, which enhances (white arrow).

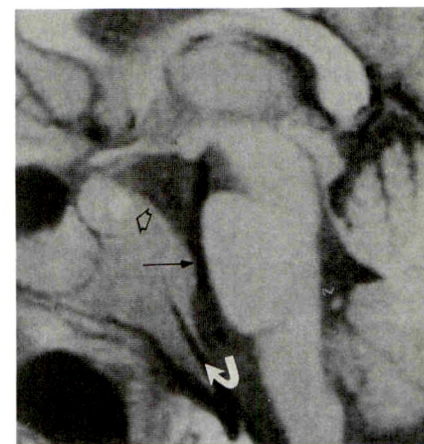


Fig. 14.—Metastatic Hodgkin's disease in a 25-year-old man with bilateral sixth-nerve palsies. Midline sagittal T1-weighted MR image shows isointense mass destroying cortex of superoposterior clivus with extension into preoptine cistern (curved arrow shows normal cortex, solid black arrow reveals extension to cistern, open arrow shows pituitary gland). Cranial nerve VI (abducens) arises at junction of pons and medulla anteriorly and ascends in preoptine cistern before entering cavernous sinus. (Courtesy of L. R. Gentry, Madison, WI.)



Fig. 15.—Posterior fossa epidermoid in a 36-year-old woman. Midsagittal T1-weighted MR image shows low-signal lesion on clivus (arrow). Decreased signal is due to reduced lipid content of tumor. Tumor is not isointense with CSF, which helps to differentiate it from an arachnoid cyst. Contrast-enhanced images showed no enhancement.

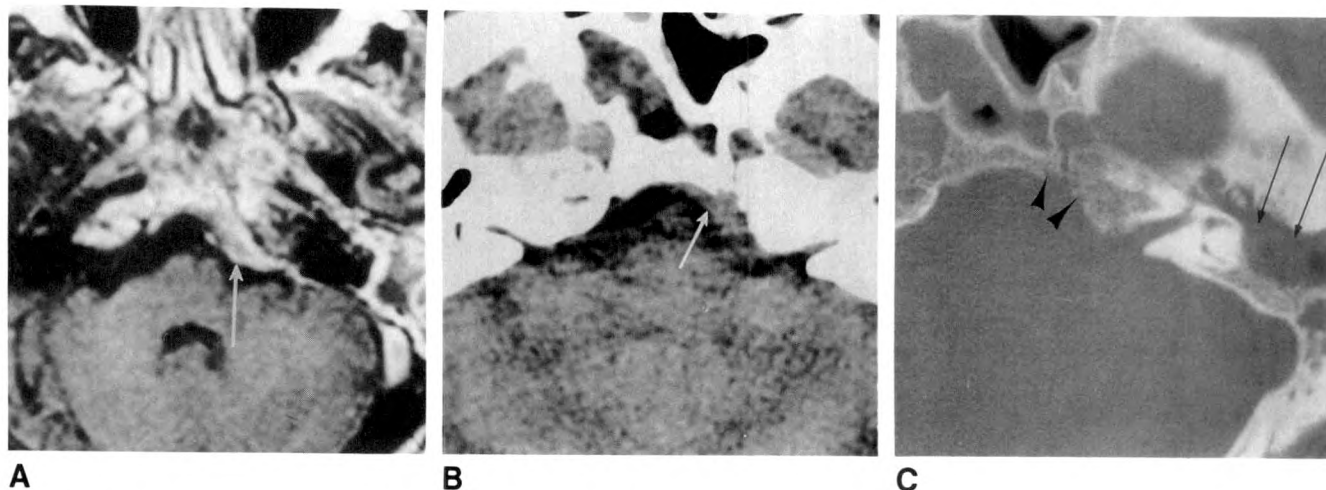


Fig. 16.—Infection of petrous apex (Gradenigo's syndrome) and clivus.

A, Contrast-enhanced axial T1-weighted MR image shows epidural enhancing mass (arrow) in cerebellopontine angle. Bone involvement cannot be determined with contrast enhancement. Gradenigo's syndrome classically consists of triad of sixth-nerve palsy, pain in trigeminal nerve distribution, and chronic otitis media in patients with petrous apicitis.

B and C, CT scans show epidural mass (white arrow) and bone erosion of petrous and clival bones (arrowheads). Note inflammatory mass in middle ear (black arrows).

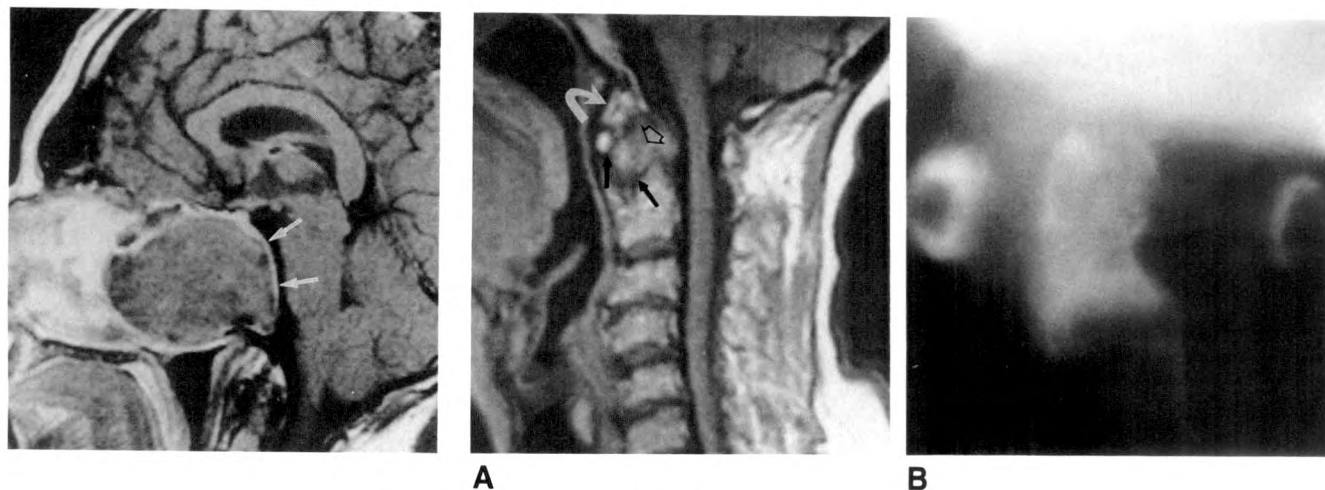


Fig. 17.—Mucocoele involving sphenoidal sinus and clivus in a 60-year-old man. Contrast-enhanced midline sagittal MR image shows mass of intermediate signal markedly expanding sphenoidal sinus and clivus. Only mucoperiosteum enhances (arrows). Classically, a mucocoele develops from obstruction of a sinal ostium.

Fig. 18.—Rheumatoid arthritis in a 64-year-old woman.

A, Midline sagittal T1-weighted MR image reveals pannus formation (open arrow) about dens disrupting normal infraclival fat (white arrow). Note markedly widened atlantodens interspace of 11 mm measuring from cortex (black line representing compact cortical bone is shown by solid black arrows). Normal atlantodens interspace in adults is 2.5 mm and in children it is up to 5 mm. Anteroposterior diameter of spinal canal is narrowed.

B, Lateral tomogram shows atlantoaxial subluxation.

and T2-weighted images. They found the normal adult clival signal usually iso- or hyperintense relative to the pons on T1-weighted images and approximately isointense with the pons on T2-weighted images. Abnormalities were hypointense in relation to the pons on the T1-weighted images and varied from diffusely hypointense to hyperintense relative to the pons on T2-weighted images.

Administration of gadopentetate dimeglumine is useful in delineating vascular anatomy and disease in the paracaval region; however, many lesions in the marrow of the clivus will enhance and become isointense with normal marrow. Thus, unenhanced images are more sensitive for detecting marrow disease, and are more sensitive than T2-weighted images [3].

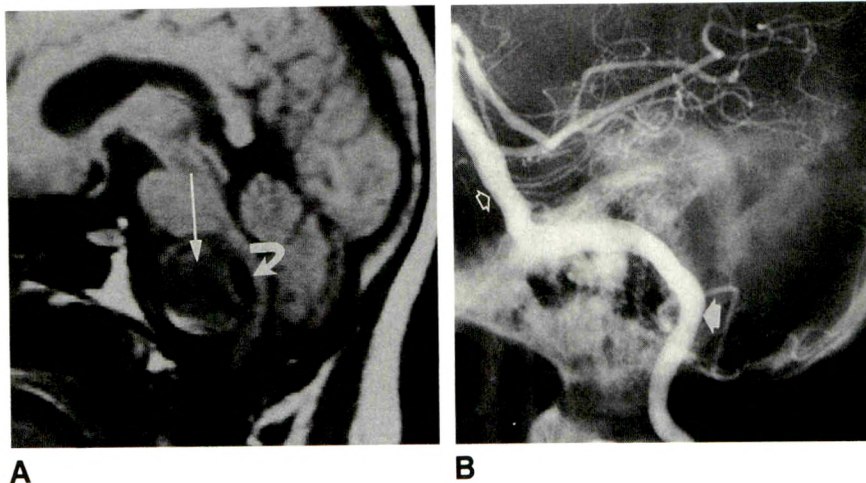


Fig. 19.—Thrombosed aneurysm in vertebral-basilar artery along dorsal clivus in a 57-year-old woman.

A, Midline sagittal T1-weighted MR image shows posterior displacement of medulla (curved arrow) by a large intermediate-signal mass (straight arrow). Round shape and predominant lack of flow void suggest thrombosed aneurysm.

B, Selected lateral vertebral arteriogram shows posterior displacement of vertebral artery (solid arrow) and ectasia of basilar artery (open arrow), but no aneurysmal filling.



Fig. 20.— β -Thalassemia in a 22-year-old man. Midline T1-weighted MR image shows replacement of normal bright fatty signal in clivus and diploetic space of calvaria by hematopoietic tissue.

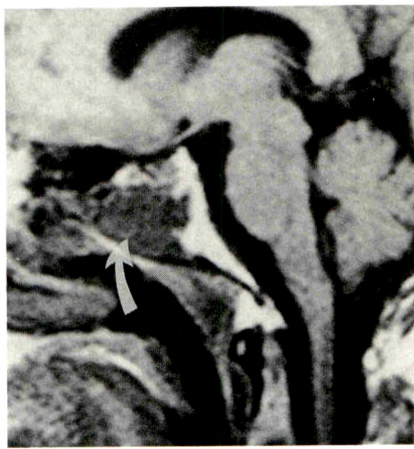


Fig. 21.—Fibrous dysplasia in a 54-year-old man. Sagittal T1-weighted MR image shows low signal in sphenoid bone and clivus (arrow). A CT scan showed osseous expansion and hazy sclerosis characteristic of fibrous dysplasia.

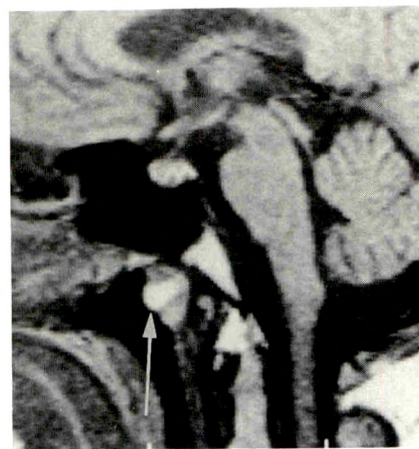


Fig. 22.—Tornwaldt's cyst in a 31-year-old man. Midline sagittal T1-weighted MR image displays a high-signal mass along midline of superior nasopharynx and ventral clivus (arrow). Track from notochordal remnants may give rise to this cyst, which can be complicated by infection.

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Case Report

Miliary Tuberculosis Involving the Brain: MR Findings

Gloria T. Gee,¹ Carlos Bazan III, and J. Randy Jenkins

We report a case of miliary cerebral tuberculosis in a 14-month-old child who began having seizures while on quadruple drug antituberculous therapy. MR imaging showed numerous round, very small enhancing lesions scattered throughout the brain, compatible with this diagnosis.

Case Report

A 14-month-old girl was referred for evaluation and control of seizures of several months' duration. Tuberculous meningitis had been diagnosed 3 months earlier on the basis of clinical history and family exposure to tuberculosis. While the child was being treated with antituberculous oral medications, she began having seizures, and left-sided weakness developed suddenly. Physical examination revealed a temperature of 38.8°C, slight weakness of the left leg, and clonus at the right ankle. The chest radiograph obtained when she was admitted showed a bilateral pattern of diffuse reticulonodular opacities suggestive of miliary pneumonia. Examination of CSF revealed an inflammatory pleocytosis and a low glucose content. A tuberculin skin test (PPD) was initially nonreactive, but a second PPD test 2 months later showed a 13 × 12 mm area of erythema after 24 hr. MR examination of the brain showed focal areas of hypointensity in the right temporoparietal and left occipital lobes on T1-weighted images and increased signal on T2-weighted images (Figs. 1A and 1B). After IV administration of gadopentetate dimeglumine (0.1 mmol/kg), we noted numerous round, very small enhancing lesions scattered throughout the brain (Fig. 1C). Most of these measured approximately 1 mm in diameter.

Discussion

Cranial tuberculosis can be described by location (meningeal or parenchymal) and type (diffuse meningitis, tubercu-

loma, tuberculous abscess, or focal cerebritis) [1]. Associated changes also are commonly encountered, such as arteritis, infarction, hemorrhage, and hydrocephalus [1, 2]. Tuberculous meningitis represents less than 5% of the cases of bacterial meningitis reported in children. Infection in children usually results from inhalation of organisms shed by adults with tuberculosis [1]. Entry of *Mycobacterium tuberculosis* into the CNS is believed to be by hematogenous spread from the lung to the meninges, where small tuberculomas are formed. These may rupture into the subarachnoid space and lead to meningitis, the severity of which is partly related to each patient's local tissue reaction to the organism.

Sixty-eight percent of children with tuberculous meningitis are reported to have concomitant miliary tuberculosis of the brain. Conversely, in only 1% of children with miliary cerebral tuberculosis does tuberculous meningitis develop subsequently [1]. Few patients with miliary tuberculosis have fever at presentation. Up to 50% have abnormal findings on chest radiographs, and only 25% have a positive tuberculin skin test [3]. Fever, an elevated erythrocyte sedimentation rate, and evidence of extracranial tuberculous infection have been reported in 32–50% of patients with cerebral tuberculomas [2, 4].

In cases of tuberculous meningitis, the basal cisterns are isodense to hyperdense compared with normal CSF on unenhanced CT scans. After IV administration of iodinated contrast medium, intense enhancement of the affected cisterns was noted. Communicating hydrocephalus is common and has been reported to be a sensitive indicator of tuberculous meningitis in children [5].

Ischemic infarcts are most common in the distribution of

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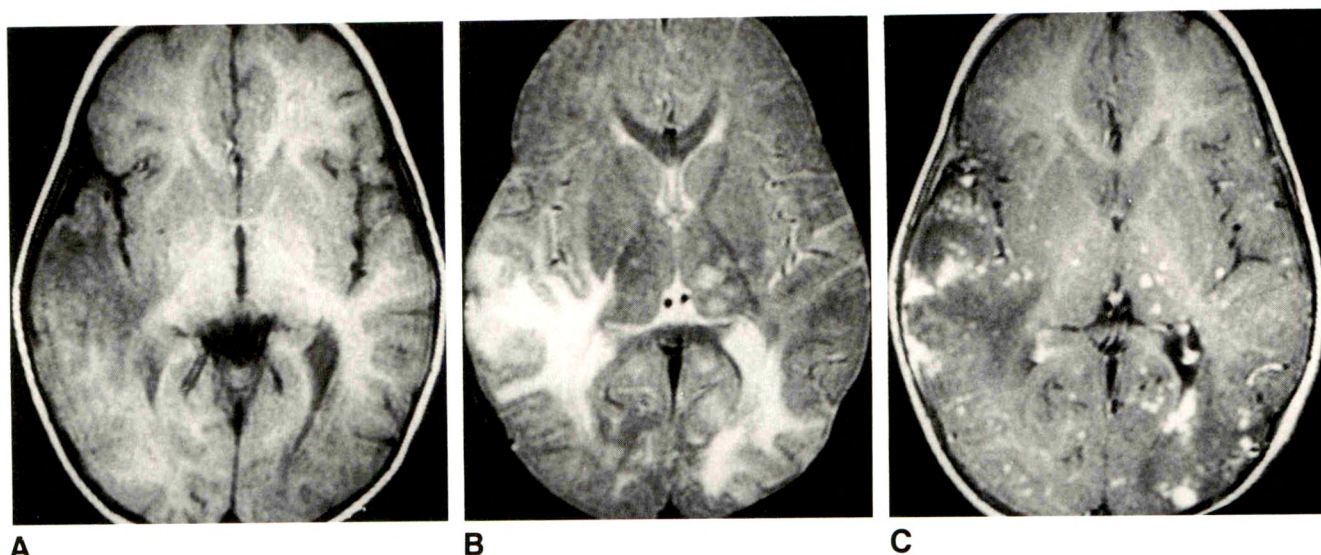


Fig. 1.—A, T1-weighted (600/20) axial spin-echo MR image shows hypointense areas in right temporoparietal lobe and left occipital lobe. B, T2-weighted (2500/20) MR image shows hyperintense areas in right temporoparietal lobe, left occipital lobe, and left side of thalamus. C, T1-weighted (600/20) axial spin-echo MR image after IV contrast administration shows numerous round, very small enhancing lesions throughout brain, with confluent areas appearing in right temporoparietal and left occipital areas.

the middle cerebral artery, including the lenticulostriate arteries [6, 7], and are associated with tuberculous arteritis caused by the basal meningitis [8]. MR imaging has been reported to be more sensitive than CT in detecting disease affecting the basal cisterns [8]. Contrast-enhanced MR is particularly useful for detecting small foci of meningeal inflammation [8].

MR is reported to be more sensitive than CT in detecting tuberculomas of the cerebral parenchyma. Tuberculomas are reported to be isointense with gray matter on T1-weighted MR images. On T2-weighted images, lesions show central hyperintensity. In some cases, a hypointense ring is apparent within the wall of the tuberculoma on T2-weighted images. Most tuberculomas are further outlined by a collar of high signal resulting from edema on T2-weighted images. Tuberculomas typically enhance after the IV administration of gadopentetate dimeglumine in a solid or ring pattern.

The MR examination in the current case showed confluent areas of enhancement in the right temporoparietal lobe and left occipital lobe, which may have represented coalescent tuberculomas, concomitant ischemic disease, or both. On T2-weighted images, multiple small hyperintense foci were scattered throughout the brain parenchyma, all of which enhanced with IV administration of contrast medium, consistent with

the diagnosis of miliary cerebral tuberculosis. The homogeneous enhancement pattern suggests that the lesions are granulomas rather than abscesses, which would be expected to have a central fluid collection.

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Femoral Artery Pseudoaneurysms: Value of Color Doppler Sonography in Predicting Which Ones Will Thrombose Without Treatment

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Barbara S. Hertzberg
Susan S. Paine
Barbara A. Carroll

OBJECTIVE. The purpose of this study was to evaluate the Doppler imaging characteristics of femoral artery pseudoaneurysms occurring after cardiac catheterization to determine if color Doppler sonography can be used to predict which pseudoaneurysms would ultimately thrombose spontaneously.

MATERIALS AND METHODS. Over a 30-month period, 24 pseudoaneurysms were studied with serial color Doppler sonography. The color flow, B-mode, and Doppler spectral images and clinical records of patients whose pseudoaneurysms demonstrated spontaneous thrombosis were compared with those of patients who required surgical repair of the pseudoaneurysm.

RESULTS. We found no statistically significant differences between the patients whose pseudoaneurysms demonstrated spontaneous thrombosis and those treated surgically in regard to clinical parameters or the volume of the pseudoaneurysm, percentage of flow within the pseudoaneurysm, ratio of forward to reversed flow velocity in the pseudoaneurysm neck, duration of diastolic flow in the pseudoaneurysm neck, or length of pseudoaneurysm neck. However, on color Doppler images, the volume of flow in the lumens of pseudoaneurysms that thrombosed spontaneously (1.8 ± 3.3 ml) was significantly smaller than the volume of flow in the lumens of those treated surgically (4.4 ± 3.2 ml, $p = .02$).

CONCLUSION. We conclude that pseudoaneurysms with small volumes of flow in the lumen are more likely to thrombose than are those with large volumes of flow in the lumen. However, color Doppler sonographic characteristics cannot be used to predict subsequent thrombosis.

AJR 159:1077-1081, November 1992

Femoral pseudoaneurysms are a known complication of cardiac catheterization in which the groin is used for vascular access [1-3]. With increased use of large-diameter arterial sheaths in interventional cardiac procedures, these pseudoaneurysms are being encountered more frequently [1, 4-6]. Traditional teaching suggests that pseudoaneurysms should be repaired surgically to avoid rupture [4, 7-9]. Although surgery is effective and safe, it is expensive and is associated with prolonged hospitalization. Recent reports raise questions about the standard surgical approach. First, many pseudoaneurysms thrombose spontaneously, suggesting that close observation and serial imaging may be indicated in some patients [5, 6, 10-13]. Second, nonsurgical sonographically guided compression-occlusion therapy has been suggested as a viable alternative to surgical management [14].

The purpose of this study was to evaluate the imaging characteristics of pseudoaneurysms managed conservatively to determine if color Doppler sonography can be used to predict which pseudoaneurysms will thrombose without treatment.

Materials and Methods

A computer-based search of sonographic studies conducted over a 30-month period (January 1, 1989, to July 1, 1991) indicated that 430 patients had had color Doppler

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sonography of the groin. Most of these examinations were performed after cardiac catheterization in order to rule out a pseudoaneurysm or arteriovenous fistula.

Seventy-nine pseudoaneurysms were identified in 78 patients; their color Doppler sonographic reports were reviewed. Fifty-five of the pseudoaneurysms were imaged only once by using color Doppler sonography and were excluded from the study group. The remaining 24 were examined at least twice with color Doppler sonography; they form the basis of this report. Twenty-three patients were included in this study. One patient had two cardiac catheterizations performed 21 months apart; each procedure was complicated by a pseudoaneurysm that was examined sequentially. Fourteen pseudoaneurysms were imaged twice (original examination and one follow-up examination) and 10 were imaged three times (original examination and two follow-up examinations). Thus, a total of 58 color Doppler sonograms were reviewed.

Patients with pseudoaneurysms were divided into two groups on the basis of clinical outcome. One group included patients with pseudoaneurysms in whom spontaneous thrombosis occurred, without surgical or nonsurgical intervention. The other group included patients who had color Doppler sonography but had surgery before thrombosis was detected. All were followed up as inpatients except for four patients who had spontaneous thrombosis who were discharged with a known pseudoaneurysm with a scheduled follow-up study. All patients had cardiac catheterization except for one in the spontaneous thrombosis group who had iliac angioplasty.

All color Doppler images were obtained by using commercially available real-time equipment (Acuson 128, Mountain View, CA) with a 5-MHz linear-array transducer. Experienced physicians or sonographers performed each examination. The sensitivity setting for color Doppler imaging was routinely adjusted for each patient such that color flow was shown throughout the femoral artery but without "bleeding" of color into the adjacent soft tissues. The following criteria were used to diagnose a pseudoaneurysm: demonstration of "swirls" of color in a hypoechoic collection outside the arterial lumen; presence of a track of color from the artery to the pseudoaneurysm, representing the "neck" of the pseudoaneurysm; and demonstration of a "to-and-fro" Doppler waveform in either the pseudoaneurysm or the

neck. Transverse and longitudinal color flow images were obtained to show the full extent of the volume of flow in the lumen of the pseudoaneurysm.

The color flow, B-mode, and image-directed Doppler waveforms and the clinical records of all patients were reviewed retrospectively. In order to determine the relative amounts of thrombus and pulsatile blood flow within each pseudoaneurysm, the entire hypoechoic collection volume and the volume of flow in the lumen were calculated. Measurements were obtained by using either electronic calipers placed on the static images at the time of the examination or hand-held calipers (Fig. 1). The volume of the pseudoaneurysm (in milliliters) was calculated by using the following formula: height $\times$ width $\times$ length $\times$ 0.52 [15]. The percentage of flow within each pseudoaneurysm was determined by using the following formula: volume of flow in the lumen $\div$ volume of the pseudoaneurysm $\times$ 100%. If a pseudoaneurysm was bilobed or trilobed, each lobe was measured separately and the values were added.

Hand-held calipers were used to determine the forward and reverse flow velocities of the Doppler spectra obtained from the neck of the pseudoaneurysm. The ratio of forward (systolic) to reverse (diastolic) velocity and the percentage of the diastolic portion of the cardiac cycle that showed flow were estimated. The length of the neck of the pseudoaneurysm was measured by using hand-held calipers.

Patients' records and catheterization reports were reviewed to determine the type of procedure used (diagnostic catheterization vs interventional catheterization), use of arterial sheaths, heparinization, use of tissue plasminogen activator, and presence of hematoma. In the group who had spontaneous thrombosis, the presence or absence of a bruit was described in only eight cases.

The clinical and demographic parameters of each group were compared by using an independent groups t-test and exact version of the χ^2 -test. The initial and final color Doppler studies that showed flow were analyzed by using the exact Wilcoxon test. Analyses were done by using Stat Xact (Cytel Software Corp., Cambridge, MA) and SAS (Version 6.04, SAS Institute, Cary, NC) software. One patient in the surgery group was excluded from all analyses because in this case we could not distinguish the margin of the pseudoaneurysm from a large hematoma.

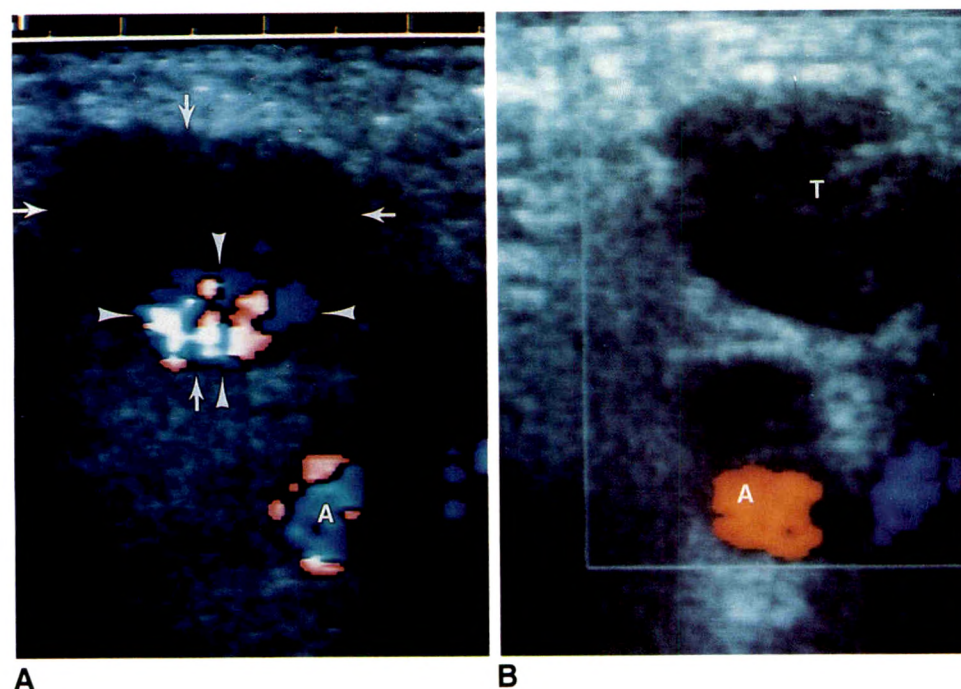


Fig. 1.—43-year-old man with congestive cardiomyopathy, 3 days after femoral artery puncture for cardiac catheterization.

A, Color Doppler sonogram shows partially thrombosed pseudoaneurysm with rim of hypoechoic thrombus. Overall volume of pseudoaneurysm was determined by measuring outer margin of hypoechoic rim (arrows). Volume of flow in lumen was determined by measuring outer margin of color Doppler signal (arrowheads). Femoral artery (A) lies deep to pseudoaneurysm.

B, Color Doppler sonogram obtained 2 days after A shows spontaneous thrombosis (T) of pseudoaneurysm. Femoral artery (A) lies deep to pseudoaneurysm.

Fourteen (58%) of the 24 pseudoaneurysms spontaneously thrombosed. Ten (42%) ultimately were treated surgically. The demographic and clinical features of both study groups are listed in Table 1. Differences between the two groups were not statistically significant.

Because the precise number of days to spontaneous thrombosis was unknown, the time to spontaneous thrombosis was calculated as a range based on the minimum and maximum intervals. The time between cardiac catheterization and the final color Doppler sonogram that demonstrated flow was used as a conservative estimate of the minimum time to thrombosis. The maximum time was based on the interval between the cardiac catheterization and the color Doppler sonogram that showed thrombosis. The minimum and maximum times for each group were averaged to give the average minimum and average maximum times to spontaneous thrombosis.

The average minimum and maximum times to spontaneous thrombosis ranged from 4.7 ± 3.2 (mean $\pm$ SD) days to 24.1 ± 27.5 days, respectively. These values include four patients who were discharged with a known pseudoaneurysm who had late follow-up studies as outpatients an average of 63 days after cardiac catheterization. If these four outpatients are considered outliers and are excluded from analysis, the average minimum and maximum times ranged from 4.7 ± 3.2 to 7.8 ± 4.9 days, respectively. The average time to surgery in the surgery group was 5.4 ± 1.5 days.

Results

The color Doppler sonographic findings of the initial study and of the last follow-up study that showed flow are listed in Tables 2 and 3. For the first imaging study, no statistically significant differences were found between the groups. For the last imaging study showing flow, the volume of flow in the pseudoaneurysm in the group with spontaneous thrombosis was significantly less than in the surgery group ($p = 0.02$). Differences in the other imaging findings were not statistically significant. However, the group with spontaneous thrombosis had a lower overall volume, lower volume of flow, lower percentage of flow, and longer pseudoaneurysm neck than did the surgery group.

In two patients in the spontaneous thrombosis group, late follow-up examinations performed 58 and 86 days after fem-

TABLE 2: Color Doppler Sonographic Findings in Initial Examination of Patients with Pseudoaneurysms of the Femoral Artery After Cardiac Catheterization

Variable	Spontaneous Thrombosis Group (n = 14)		Surgery Group (n = 9)		Wilcoxon p Value
	Mean $\pm$ 1 SD	Median	Mean $\pm$ 1 SD	Median	
Volume of pseudoaneurysm (ml)	8.8 ± 10.2	4.3	11.5 ± 9.5	10.7	0.54
Volume of flow in lumen of pseudoaneurysm (ml)	1.8 ± 2.5	0.88	3.1 ± 2.5	2.3	0.28
Volume of flow in lumen/volume of pseudoaneurysm (%)	32 ± 29	28	36 ± 31	29	0.77
Ratio of forward to reverse flow velocity in neck of pseudoaneurysm	2.4 ± 0.68	2.3	2.0 ± 1.1	1.8	0.43
% Diastole	83 ± 31	100	69 ± 35	75	0.34
Length of pseudoaneurysm neck (cm)	1.29 ± 0.56	1.2	1.9 ± 0.64	0.8	0.35

Note.—All p values were determined by using the exact version of the Wilcoxon test. The values given for volume of flow in lumen/volume of pseudoaneurysm are derived from the mean and standard deviation of each individual measurement. % Diastole = the percentage of the diastolic portion of the cardiac cycle that demonstrated flow.

TABLE 1: Demographic and Clinical Features of Patients with Pseudoaneurysms of the Femoral Artery After Cardiac Catheterization

Variable	Patients Who Had Spontaneous Thrombosis (n = 14)	Patients Who Had Surgery (n = 9)	p Value
Age, years (mean $\pm$ 1 SD)	67 ± 11	72 ± 9	0.33
Men	7 (50)	4 (44)	1.00
Women	7 (50)	5 (56)	1.00
Arterial sheath	13 (93)	9 (100)	1.00
Interventional procedure	9 (64)	4 (44)	0.42
Heparin during procedure	13 (93)	8 (89)	1.00
Use of tissue plasminogen activator	3 (21)	0 (0)	0.25
Bruit	7 (88)	8 (89)	1.00
Hematoma	14 (100)	9 (100)	1.00

Note.—Numbers in parentheses are percentages. An exact version of the χ^2 -test was used for analysis of all variables except age. In the spontaneous thrombosis group, the presence or absence of a bruit was described in only eight cases.

oral puncture detected no abnormality at the site of the previously detected pseudoaneurysm. Thus, it was not possible to measure volumes of the pseudoaneurysms in these cases. These two final data points were excluded from Figures 2A and 3A.

Figure 2 shows the actual volumes of the pseudoaneurysms for both groups. Here, it can be seen that five patients in the group who had spontaneous thrombosis and two in the surgery group had an increase in volume on follow-up examinations. The others had no change or a decrease in volume. Figure 3 shows the volume of flow in the lumen during the course of serial studies. In both groups, most patients had no change or a decrease in volume on follow-up examinations. One patient in the spontaneous thrombosis group had a decrease in the volume of flow in the lumen after an initial increase in volume. Three patients in the surgery group had an increase in the volume of flow in the lumen on follow-up studies; in one of these, the increase in volume of flow followed a decrease in the volume of flow.

On the initial examination, 13 of 14 patients in the spontaneous thrombosis group had a circumferential thrombus; one had no detectable peripheral thrombus. On the initial examination, eight of 10 patients in the surgery group had a circumferential thrombus. Four patients in the spontaneous thrombosis group had bilobed pseudoaneurysms; two of

TABLE 3: Color Doppler Sonographic Findings in Final Follow-up Study Showing Flow in Patients with Pseudoaneurysms of the Femoral Artery After Cardiac Catheterization

Variable	Spontaneous Thrombosis Group (n = 14)		Surgery Group (n = 9)		Wilcoxon p Value
	Mean $\pm$ 1 SD	Median	Mean $\pm$ 1 SD	Median	
Volume of pseudoaneurysm (ml)	8.9 $\pm$ 11.2	3.8	12.0 $\pm$ 8.4	16.0	0.28
Volume of flow in lumen of pseudoaneurysm (ml)	1.8 $\pm$ 3.3	0.47	4.4 $\pm$ 3.2	4.5	0.02
Volume of flow in lumen/volume of pseudoaneurysm (%)	29 $\pm$ 30	16	46 $\pm$ 34	41	0.19
Ratio of forward to reversed flow velocity in neck of pseudoaneurysm	2.3 $\pm$ 1	2	3.3 $\pm$ 1	2.8	0.24
% Diastole	76 $\pm$ 36	100	75 $\pm$ 35	100	1.00

Note.—All *p* values were determined by using the exact version of the Wilcoxon test. The values given for volume of flow in lumen/volume of pseudoaneurysm are derived from the mean and standard deviation of each individual measurement. % Diastole = the percentage of the diastolic portion of the cardiac cycle that demonstrated flow.

these developed during the follow-up period. In the surgery group, two patients had bilobed pseudoaneurysms and one had a trilobed pseudoaneurysm. One of the bilobed pseudoaneurysms developed during the follow-up period.

Discussion

Traditionally, femoral pseudoaneurysms have been treated surgically to avoid the potential complication of rupture [4, 7–9]. Recently, nonsurgical sonographically guided compression-occlusion therapy has been suggested as a feasible

substitute to surgical management; however, complications associated with this procedure have been reported [14]. Inasmuch as some pseudoaneurysms thrombose spontaneously, determining imaging parameters that could be used to predict spontaneous thrombosis would be important to potentially obviate other intervention.

This study shows that pseudoaneurysms with small volumes of flow in the lumen are more likely to thrombose than are those with larger volumes of flow. This characteristic was statistically significant only for the final sonogram showing flow. Although no other differences in imaging characteristics were statistically significant, the overall volume of the pseudoaneurysm, the volume of flow in the lumen, and the percentage of flow were all lower and the neck of the pseudoaneurysm was longer in the group with spontaneous thrombosis than in the surgery group. In both groups of patients, the volume of the pseudoaneurysm and the volume of flow in the lumen tended to remain unchanged or to decrease.

The suggestion that a pseudoaneurysm with a small volume of flow in the lumen is more likely to thrombose than one with a larger volume of flow has important limitations. First, there is substantial overlap between the volume of flow in the lumen in both groups of patients. Second, the diameter of the lumen that would distinguish between the means of the two groups is only approximately 0.5 cm, as a cubic function is involved. Although a variation of this magnitude can be caused by differences in sensitivity settings of the instruments rather than by true differences in volumes, we attempted to standardize our technique in order to reduce this possible source of error. Finally, the differences in the volume of flow in the lumen between the two groups of patients was statistically significant only for the final follow-up study showing flow. Thus, we think that in clinical practice, findings on color Doppler imaging cannot be used alone to predict subsequent thrombosis.

This study confirms previous reports [10–13] that a substantial proportion of pseudoaneurysms occurring after cardiac catheterization will thrombose spontaneously. On average, patients had surgery within 1 day of the average minimum time to spontaneous thrombosis. This suggests that if the surgery patients had been observed longer, more of the

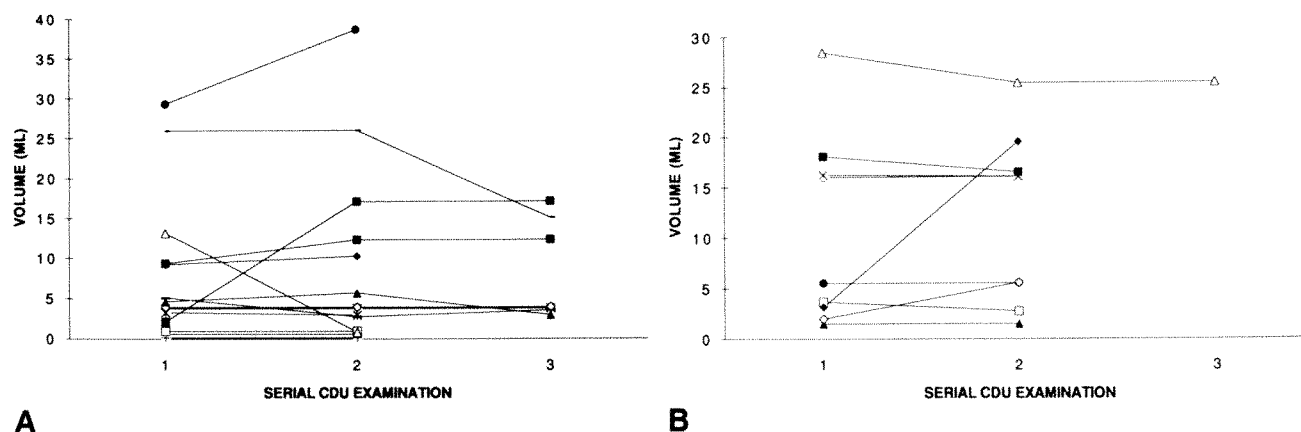


Fig. 2.—A, Graph shows actual volumes of pseudoaneurysm on follow-up color Doppler (CDU) images in patients with spontaneous thrombosis (n = 14).

B, Graph shows actual volumes of pseudoaneurysm in patients who had surgery (n = 9).

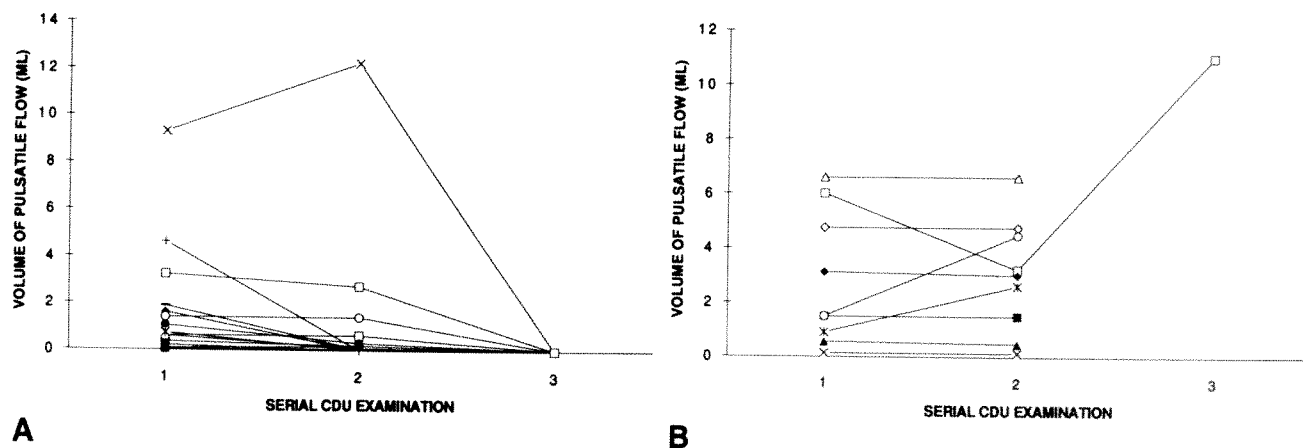


Fig. 3.—A, Graph shows actual volumes of flow in lumen of pseudoaneurysm on follow-up color Doppler (CDU) images in patients with spontaneous thrombosis ($n = 14$).

B, Graph shows actual volumes of flow in lumen of pseudoaneurysm in patients who had surgery ($n = 9$).

pseudoaneurysms might have thrombosed spontaneously. Indeed, it has been speculated that small, asymptomatic, stable pseudoaneurysms are likely to thrombose [5, 6, 13]. However, our retrospective study reported here included only those patients for whom a clinical decision was made to follow up the pseudoaneurysm by using color Doppler sonography. Therefore, our results may not be applicable to the general population of patients who have a pseudoaneurysm as a complication of femoral artery puncture. Findings in patients who required prompt surgical repair were not evaluated. As these patients were treated differently, it could be argued that if they had been included, any differences found on color Doppler images could be the result of selection bias.

We think that comparing the color Doppler findings between the two groups of patients in this study is valid because the patients had similar clinical and demographic characteristics, and because a clinical decision was made to treat each of these groups conservatively.

It has been reported that spontaneous thrombosis occurs in a centripetal fashion and that a rim of peripheral thrombus suggests eventual spontaneous thrombosis [10]. In our cases of spontaneous thrombosis, such a rim was detected. However, it was also seen in the patients in the surgery group, perhaps suggesting that the pseudoaneurysms in these patients were heading toward spontaneous thrombosis. It has also been suggested that pseudoaneurysms with long necks are more likely to thrombose spontaneously than are those with short necks [6]. No significant difference was found in the lengths of the necks of the pseudoaneurysms in our patients, so this suggestion is not supported by our data.

Previous reports have suggested that spontaneous thrombosis is unlikely to occur in pseudoaneurysms in which no peripheral thrombus is detected and that prompt surgery may be indicated in these patients [10]. Our one case of spontaneous thrombosis in which the first color Doppler study showed 100% flow without peripheral thrombus argues against this hypothesis. Furthermore, a multilobulated pseudoaneurysm does not necessarily imply a poor prognosis, as these thrombosed spontaneously in our study. The multilobulated pseudoaneurysms that developed during the follow-up interval may reflect an attempt to reduce wall tension of the pulsating pseudoaneurysm, as hypothesized by Kotval et al. [10]. Finally, the two cases in which follow-up color Doppler

sonography showed no abnormality at the site of the previously detected pseudoaneurysm indicate that pseudoaneurysms may resolve in a fashion similar to that of a hematoma.

In summary, for pseudoaneurysms of the femoral artery that occur after cardiac catheterization, thrombosis is statistically more likely in those with small volumes of flow in the lumen than in those with large volumes of flow. However, color Doppler findings alone cannot be used to predict subsequent thrombosis.

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Book Review

Peripheral Vascular Sonography. A Practical Guide. By Joseph F. Polak. Baltimore: Williams & Wilkins, 364 pp., 1992. \$75

In this age of texts written by more than one author, it is refreshing to find a comprehensive text in an area of current interest that has only one. As the field of vascular sonography begins to achieve relative maturity, it is an appropriate moment for a text such as this, which summarizes what has been learned over the past few years. As a major contributor to the literature in vascular sonography, Dr. Polak is in a good position to provide this kind of overview.

In a relatively short space, the book covers the field of vascular sonography in a comprehensive manner. It has chapters on the physics of Doppler sonography, a lengthy discussion of the pathophysiology of vascular disease, and a review of other noninvasive vascular tests. It also has detailed chapters on carotid evaluation; diagnosis of acute and chronic venous disorders, including chronic venous insufficiency; peripheral arterial Doppler imaging; and post-operative vascular imaging. Both gray-scale and color Doppler sonograms are provided; they are of generally excellent quality. Unfortunately, the color images are collected into one section at the beginning of the book, which makes referring to them somewhat tedious.

Rather than being an encyclopedic reference text, this book is more along the lines of a personal tour through the field of peripheral vascular sonography (carotid sonography, although not really peripheral, is included). The book is written from the standpoint of the angiographer. The author provides extensive discussions of the prevalences and causes of various vascular diseases and detailed

descriptions of available treatments. This aspect of the book will be welcomed by many who come to vascular sonography without the depth of knowledge in vascular disease necessary to assess the significance of sonographic findings. On the other hand, some of the discussions on pathophysiology become redundant and digress some distance from the book's primary focus.

Another weak point is the absence of footnotes in the text, which limits the usefulness of the book as a reference. A thorough list of suggested readings is provided at the end of each chapter. However, this is of little help when the author quotes numerical data, as he does frequently throughout the book, and the reader would like to refer to the original source. I hope that this will be rectified in subsequent editions.

Nevertheless, the book is packed with the kind of detailed, clinically useful pointers that are usually sorely lacking in the typical radiology textbook, not to mention in scientific articles, and that can be provided only by someone with as deep a knowledge of his field as Dr. Polak. This book will be especially welcomed by radiology residents, fellows, and sonographers in training and by any radiologists, angiographers, or sonographers who are about to embark on the practice of peripheral vascular sonography.

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Closure of the Ductus Venosus in Neonates: Findings on Real-Time Gray-Scale, Color-Flow Doppler, and Duplex Doppler Sonography

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OBJECTIVE. Our objective was to document the anatomy, flow pattern, and time of closure of the ductus venosus in healthy full-term neonates.

SUBJECTS AND METHODS. We examined the ductus venosus in 73 neonates by using gray-scale sonography, color flow imaging, and duplex Doppler sonography. Each neonate was examined 1–2 days after birth, 6–7 days after birth, and then every 3–4 days until closure was confirmed or the neonate was 18 days old. The length, width, and color flow and duplex Doppler characteristics of the ductus were noted. Closure of the ductus at 6–7 days after birth was examined with respect to birth weight, hemoglobin level, and gestational age.

RESULTS. The ductus venosus, extending from the left portal vein to the inferior vena cava, was identified with all three techniques. The ductus was patent in all 73 neonates 1–2 days after birth. It was still patent in 41 (68%) of 60 neonates reexamined 6–7 days after birth and in two of three neonates (11% [7/60]) reexamined 17–18 days after birth. Blood flow within the ductus was cephalic, in a constant venous waveform. Initial flow velocity ranged from 0.15 to 0.70 m/sec and decreased consistently in subsequent examinations. There was no significant difference in birth weight, hemoglobin level, or gestational age between the group whose ductus was closed and the group whose ductus was open at 6–7 days after birth.

CONCLUSION. The ductus venosus in neonates is consistently detectable on sonography. It is patent in a greater percentage of neonates, and for a longer time, than was previously shown with conventional radiographic studies with angiography.

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The ductus venosus is the continuation of the umbilical vein. It originates from the left portal vein opposite the termination of the umbilical vein. It ends in the left hepatic vein, near the confluence of the hepatic veins and the inferior vena cava. During fetal life, the ductus venosus provides a bypass of the portal venous system for blood returning through the umbilical vein. With the postpartum closure of the umbilical vein, flow in the ductus venosus decreases and eventually ceases, with the final fibrotic transformation of the ductus venosus into the ligamentum venosum.

We used real-time gray-scale sonography, color flow imaging, and duplex Doppler sonography to study the anatomy, blood-flow pattern, and timing of closure of the ductus venosus in neonates. We determined if birth weight, hemoglobin levels, or gestational age influenced the time of closure.

Subjects and Methods

We examined 73 full-term neonates 1–2 days after birth. All neonates had normal birth weights, Apgar scores, gestational ages, hemoglobin levels, and findings on physical examination. The neonates were examined again 6–7 days after birth, and then every 3–4 days until they were 18 days old or until closure of the ductus venosus was confirmed. This was a healthy outpatient population, and the compliance for returning for reexamination was 40–80% at different ages.

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All examinations were performed with an Aloka Color Doppler SSD-870 unit (Aloka Co., Tokyo) and a 5-MHz sector transducer. Examinations were recorded as both color videotape and black and white paper images. The ductus venosus was detected in a near-sagittal plane by means of its uninterrupted course from the left portal vein to the inferior vena cava.

In initial examinations, two-dimensional real-time gray-scale sonography was used to measure the length and diameter of the ductus venosus. Color flow imaging was used to determine directional flow in the portal vein, the ductus venosus, the left hepatic vein, and the inferior vena cava. Duplex Doppler imaging was used to show the waveform of flow and its velocity. The Doppler angle ranged from 45° to 60°.

The percent patency of the ductus venosus was calculated on the basis of the entire study population. In order to do this, two assumptions were made: first, that a closed ductus would not reopen (neonates with closed ductus were not reexamined); second, that neonates who did not return for examination had the same percentage of ductus patency as those of the same age who were examined.

Student's *t* test was used to correlate the time of closure of the ductus venosus with birth weight, gestational age, and hemoglobin level.

Results

The ductus venosus was detected in all neonates on initial real-time gray-scale sonograms (Fig. 1). Its length ranged from 1.1 to 1.9 cm, its diameter from 1 to 2 mm. On color Doppler sonograms, flow was cephalic from the left portal vein to the inferior vena cava.

Duplex Doppler imaging showed cephalic flow with a constant venous waveform (Fig. 2). Initial flow velocity varied from 0.15 to 0.70 m/sec. Flow was shown in all 73 neonates (100%). At 6–7 days, flow was shown in 41 (68%) of the 60 neonates who returned for examination; at 9–10 days, in 14 of 32 (30% [18/60]); at 13–14 days, in seven of 13 (16% [10/60]); and at 17–18 days, in two of three (11% [7/60]). The percentage of neonates with ductus patency at a given examination refers to the total population, including neonates examined at a given age, those not returning for examination,

and those previously determined to have a closed ductus. For example, 32 of the 41 neonates whose ductus venosus was patent at 6–7 days returned for reexamination at 9–10 days. Because 14 (44%) of 32 neonates had patent ductus at 9–10 days, it was assumed that 44% (four) of the nine neonates who were not reexamined at 9–10 days also had patent ductus. Thus, a total of 18 (30%) of 60 neonates were considered to have patent ductus at 9–10 days.

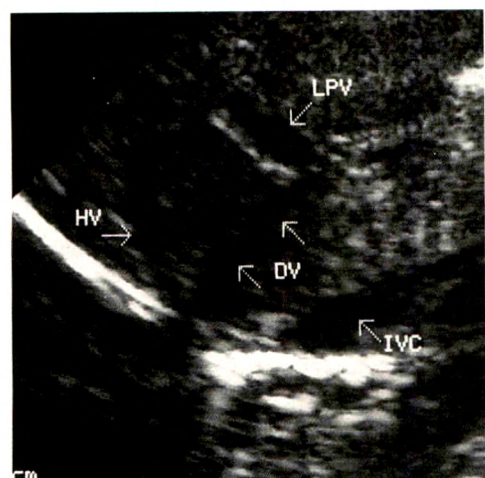
The times of closure of the ductus venosus for the study population are shown graphically in Figure 3. The closed ductus venosus appeared as a thin anechoic channel; no flow was seen on color Doppler sonography and no signal was visible on the Doppler waveform.

Comparing the group of neonates whose ductus venosus was patent at 6–7 days with the group whose ductus venosus was closed, we found no significant difference with respect to mean birth weight (3399 g vs 3441 g), range of gestational ages (38–42 weeks vs 38–41 weeks), or mean hemoglobin level (16.8 g vs 16.9 g).

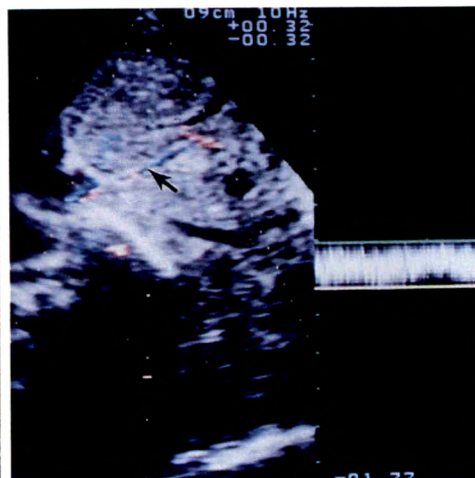
Discussion

During fetal life, the ductus venosus functions as a low-resistance bypass for umbilical venous blood to reach the systemic circulation [1]. Previously, the fetal ductus venosus was thought to be a low-flow vessel [2], with maximal flow occurring in response to placental failure or hypovolemia [3, 4]. However, recent sonographic studies [5] have shown the ductus is a high-flow vessel in the fetus during the latter half of gestation.

Neither the average age at which the ductus venosus normally closes nor the exact mechanism of its closure has been completely elucidated. Rudolph et al. [6] found a closed ductus venosus in 30% of neonates. According to Lind [7], the ductus venosus closes within minutes after birth. Linde et al. [8], who attempted cardiac catheterization via the umbilical venous route, reported that the ductus venosus was patent in 60% of neonates 6 days after birth. Others [9–11]



1



2

Fig. 1.—Sagittal gray-scale sonogram shows ductus venosus (DV) between left portal vein (LPV) and inferior vena cava (IVC). HV = left hepatic vein.

Fig. 2.—Color flow Doppler image shows ductus venosus color-coded blue (cephalic flow). Cursor is placed in middle of ductus venosus (arrow), and a constant venous waveform in a negative direction is displayed.

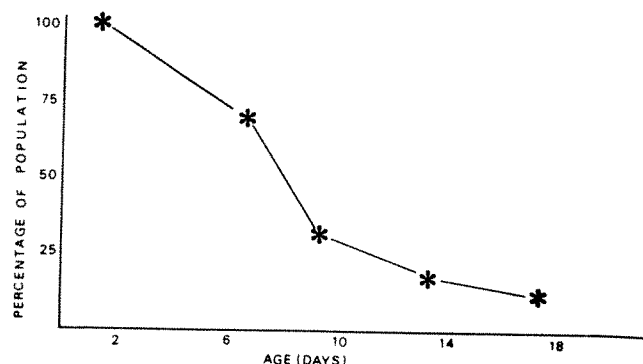


Fig. 3.—Graph of timing of closure of ductus venosus in our study population. Each point represents the percentage of the total population with a patent ductus venosus at the given age.

have observed that the ductus venosus of newborn lambs and human infants can be visualized for about 3–4 days after birth, and in some cases as late as 12 days. It must be emphasized that in these previous studies, conventional radiographs after injection of iodinated contrast material were used to determine patency, and the human subjects were neonates requiring cardiac catheterization or other therapeutic intervention. These results are cited in standard texts [12].

Our data indicate that previous reports of closure of the ductus venosus at or shortly after birth are erroneous. We were able to detect the ductus venosus extending from the portal vein to the inferior vena cava in all neonates we examined. Flow was easily shown with both color flow and duplex Doppler imaging. Flow velocity on the initial examination was consistent with subsequent measurements; values decreased until closure was shown. Flow velocity in the ductus venosus in the neonate was similar to that in late fetal life [5]; however, the waveform in fetal life reflects the cardiac cycle [5], although we found a fairly constant venous waveform. This difference may be due to a damping of flow pulsatility caused by the beginning of ductus closure.

For the clinician, imaging studies of the ductus venosus may have practical applications. The umbilical venous route is used for the emergent administration of blood, IV fluid, and medication, as well as for cardiac catheterization and interventional cardiac procedures. The misplacement of a catheter within the portal system rather than within the right atrium may result in serious complications, including hemorrhagic liver necrosis [13].

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Book Review

A Radiologic Approach to Diseases of the Chest. By Irwin M. Freundlich and David G. Bragg. Baltimore: Williams & Wilkins, 560 pp., 1992. \$95

The subspecialty of thoracic radiology has changed almost beyond recognition in the past 10 years, both because of advances in imaging technology and because of changes in the clinical understanding of pulmonary problems. Drs. Freundlich and Bragg assembled an array of well-known subspecialty experts to deliver a review of current topics in chest radiology (including chest radiology in children). The authors all have outstanding reputations in their respective subjects. All are radiologists except Anthony Newman-Taylor and Margaret Turner-Warwick, who have contributed an excellent chapter on cryptogenic fibrosing alveolitis (for American audiences, this should have been translated as idiopathic pulmonary fibrosis). The result is a work that is both authoritative and reasonably comprehensive.

The opening segment of the book includes an introduction to the interpretation of chest radiographs. This is followed by chapters on physiologic imaging of the lung and on lung anatomy. These are followed by 13 chapters on approaches to imaging problems, ranging from imaging neonates to imaging immunocompromised patients. These concise chapters convey basic but vital information and will be valuable to first-year residents. This section alone justifies the cost of this book. The third section covers specific groups of lung diseases in greater detail and places them in their clinical context. A final section is devoted to special topics, including AIDS, digital chest radiography, and MR imaging of the thorax.

A radiologist's skills as an interpreter of chest images are of little importance if he or she is ignorant of the clinical issues involved in the study of individual patients. It is gratifying to see that the authors have included much useful clinical information on their selected topics. Importantly, the limitations as well as the benefits of high-technology imaging techniques are clearly summarized.

The contributions are supported by just the right number of selected references, including many classic papers. The illustrations, with few exceptions, are of good quality and are large enough to show the pertinent radiologic features. Occasional inclusion of a coned view of a chest radiograph would have been useful to focus on the specific abnormality being described. In some chapters, arrows would be welcome to point out subtle radiologic signs.

The format of this book leads inevitably to some overlap (for example, two chapters on mediastinal abnormalities), but this becomes a strength rather than a weakness, as different contributors emphasize different aspects of a problem. Equally inevitable in a single-volume text are some omissions and areas of underemphasis. The chapter on chest anatomy is well illustrated, but the limited allocation of space does not allow a detailed description of chest radiographic anatomy. The diaphragm and chest wall and drug-induced lung disease are not included as topics of discussion. Although the book has comprehensive sections on chest radiographic and MR techniques, a paragraph or two on tailoring chest CT techniques would be useful. I would also welcome a list of definitions of standard terms in chest radiology, such as that published by the Fleischner Society. However, the strengths of this book far outweigh these few deficiencies.

How does this book compare with existing texts? In fact, surprisingly few comprehensive texts of thoracic imaging have been published. Many residents still use Fraser and Pare's *Synopsis of Diagnosis of Diseases of the Chest*. Although Freundlich and Bragg's book is a little less comprehensive than the *Synopsis*, it is clearly more up-to-date, with a heavier emphasis on imaging, and subjectively easier to read. On the other hand, *Imaging of Diseases of the Chest*, published in 1990, by Armstrong, Wilson, and Dee, is larger (914 pages) and somewhat more costly, but more inclusive than the Freundlich and Bragg book.

A Radiologic Approach to Diseases of the Chest, supplemented by the selected references, includes virtually all the information residents should acquire during their residency. I will happily recommend it to the residents at my institution. I am also certain that the book will be valuable to more experienced, practicing radiologists who will value the up-to-date and authoritative information it provides. It seems destined to become one of the standard texts of thoracic imaging for the 1990s.

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Pictorial Essay

Giant Fistula Between the Right Coronary Artery and the Left Ventricle: Diagnostic Significance of Right Posterior Oblique Chest Radiograph

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Congenital coronary artery fistulas are uncommon. The prevalence of coronary artery fistulas in adults has been estimated as 0.13% [1]. Most of these fistulas communicate with the right atrium or ventricle or with the pulmonary artery; those emptying into the left atrium or ventricle are quite rare [2, 3]. Usually,

patients with coronary artery fistula do not have clinical symptoms, and their chest radiographs do not show the corresponding shadow because the fistula is hemodynamically insignificant. When the fistula is large, however, chest radiographs show the secondary hemodynamic changes, such as cardiac enlargement

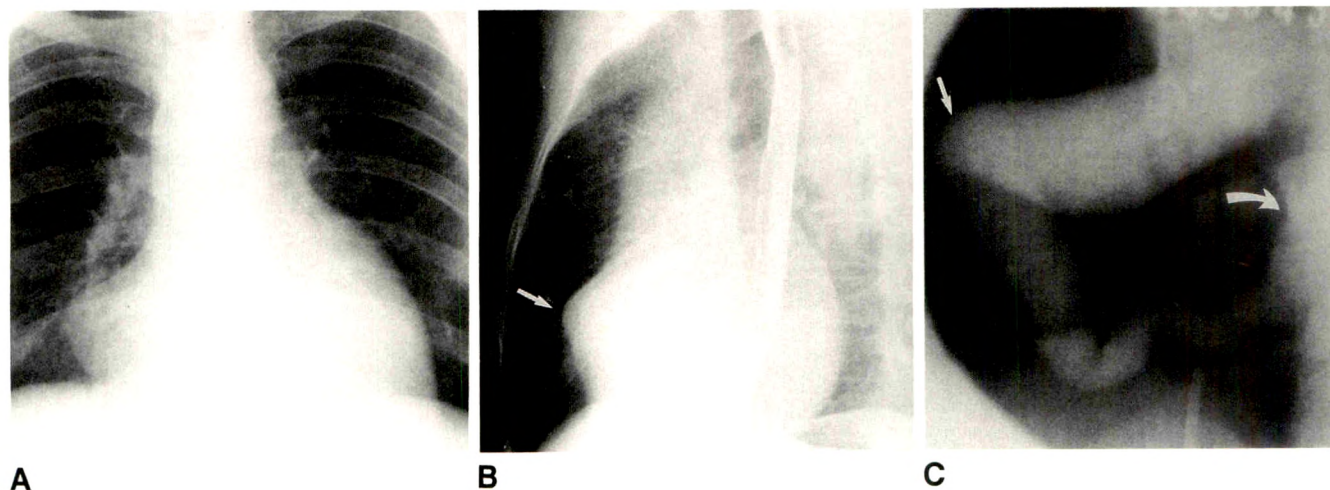


Fig. 1.—37-year-old man with giant fistula between right coronary artery and left ventricle.
A, Posteroanterior chest radiograph shows prominent right border of heart.
B, Chest radiograph in right posterior oblique projection shows steep angle associated with double contour (*arrow*) on right border of heart.
C, Right coronary arteriogram in left anterior oblique view verifies that angled proximal segment of dilated right coronary artery (*straight arrow*) causes triangular shadow shown in **B**. *Curved arrow* indicates site where fistula in right coronary artery empties into left ventricle.

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or increased pulmonary vasculature, depending on the emptying site. Moreover, the silhouette of the dilated tortuous vessel itself can be seen on the chest radiograph. We have examined four patients, each of whom had a giant fistula in the right coronary artery emptying into the left ventricle, proved by coronary angiography. In this essay, we illustrate the chest radiographs of these patients and describe the radiologic features that permit a specific diagnosis or suggest a coronary artery fistula.

We examined four patients, each of whom had a giant fistula between the right coronary artery and the left ventricle.

All four patients were men between 37 and 45 years old (mean age, 41 years). The chief signs and symptoms were angina in two patients and fatigability in two patients; all had an end-diastolic murmur.

Routine chest radiographs were obtained in the standard four views: posteroanterior, lateral, left posterior oblique, and right posterior oblique. Cardiac catheterization and angiocardiography were done within a few days after the chest radiographs were obtained. Aortography and selective coronary arteriography were performed in right and left anterior oblique

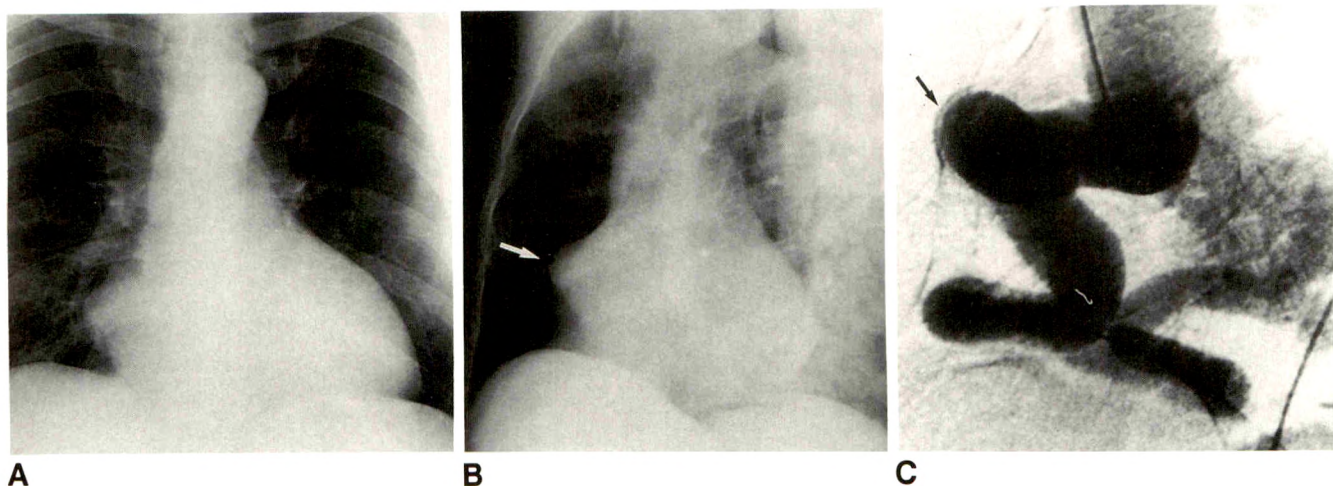


Fig. 2.—41-year-old man with giant fistula in right coronary artery that empties into left ventricle.
A, Posteroanterior chest radiograph shows prominence in middle of right border of heart.
B, Right posterior oblique radiograph shows angle in upper part of right border of heart, accompanied by double contour (arrow).
C, Digital subtraction angiogram in left anterior oblique view shows markedly dilated and tortuous right coronary artery. Angled proximal segment (arrow) was confirmed to be responsible for triangular shadow in B.

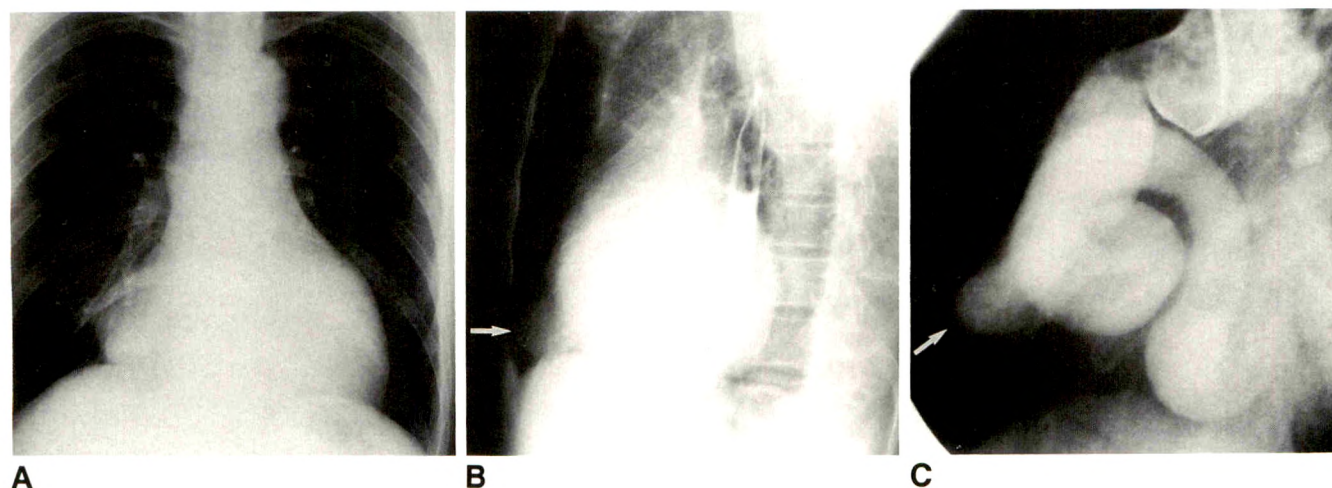


Fig. 3.—45-year-old man with giant fistula in right coronary artery connecting with left ventricle.
A, Posteroanterior chest radiograph shows mild protrusion of right border of heart.
B, Right posterior oblique radiograph shows tongue-like projection (arrow) at lower end of right border of heart.
C, Right coronary arteriogram in left anterior oblique view reveals abrupt bend in acute marginal segment (arrow), which caused shadow shown in B.

views with biplane cineangiography (Angiomax, General Electric, Milwaukee, WI). One patient was examined with digital subtraction angiography.

Chest Radiographs

Posteroanterior chest radiographs revealed a prominent right border of the heart in all but one patient. That patient had a smooth, flat right border of the heart. In another case, the right upper border of the heart looked angled (Fig. 1A). In

this patient, a chest radiograph in the right posterior oblique view showed that the upper right border of the heart was prominent (Fig. 1B). Right coronary arteriography in the left anterior oblique view revealed a markedly dilated right coronary artery; its proximal segment caused the prominence seen on the right posterior oblique radiograph (Fig. 1C).

A second patient had a prominence at the middle of the right border of the heart shown on a posteroanterior chest radiograph (Fig. 2A). In the right posterior oblique view, a shadow accompanied by a double contour was observed at

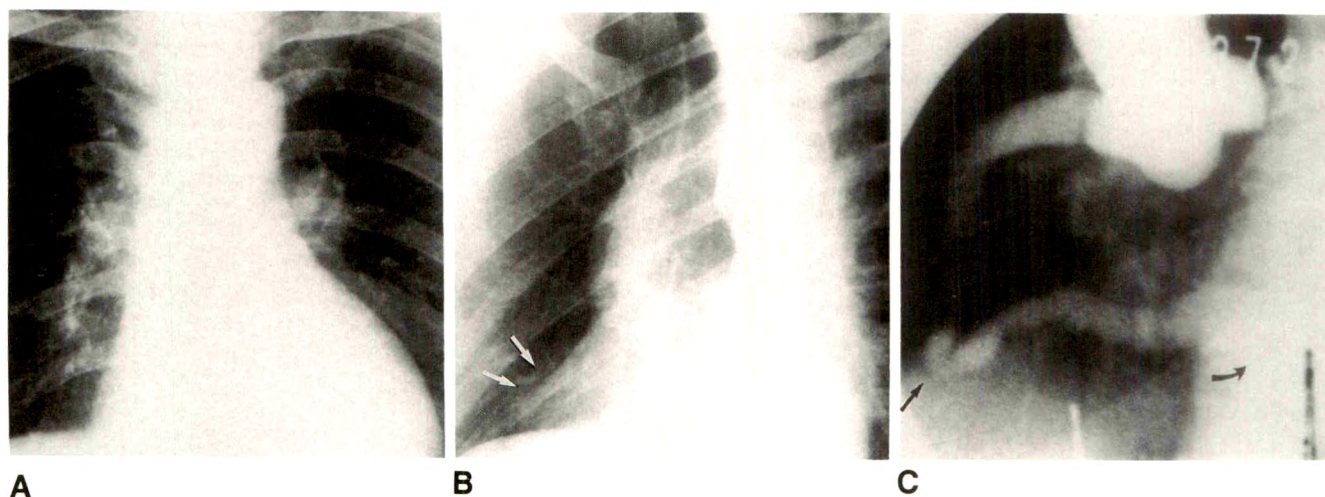


Fig. 4.—42-year-old man with giant fistula in right coronary artery communicating with left ventricle.
A, Posteroanterior chest radiograph shows flat right border of heart.
B, Right posterior oblique radiograph, however, shows right border of heart as angled at lower end (arrows).
C, Aortogram in left anterior oblique view reveals acute marginal segment of right coronary artery is angled (straight arrow), creating shadow shown in B. Curved arrow indicates anastomosis of fistula in right coronary artery with left ventricle.

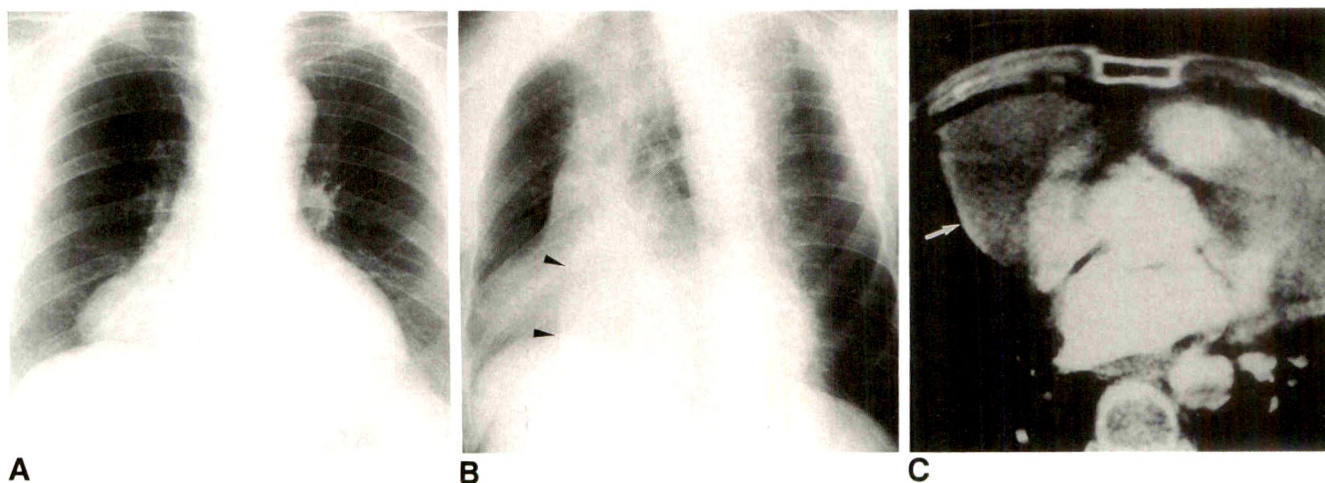


Fig. 5.—57-year-old woman with pericardial cyst.
A, Posteroanterior chest radiograph shows markedly protruded right border of heart.
B, Right posterior oblique radiograph shows right border of heart (arrowheads) clearly in bulky shadow of pericardial cyst.
C, Contrast-enhanced CT scan shows cystic mass adjacent to right atrium (arrow).

the upper right border of the heart (Fig. 2B). Digital subtraction angiography in the left anterior oblique position revealed a markedly dilated right coronary artery with an abrupt bend in the proximal segment (Fig. 2C).

In the third patient, the right border of the heart had a vague protrusion (Fig. 3A). In the right posterior oblique view, an angled tonguelike projection was observed at the lower portion of the right border of the heart (Fig. 3B). Coronary arteriography showed a dilated right coronary artery with steep angling of the midsegment. The angled midsegment caused the density of the lower projection in the right posterior oblique view (Fig. 3C). In the fourth patient, the right border of the heart appeared normal (Fig. 4A). In the right posterior oblique view, however, a density similar to that seen in the third patient was observed at the lower part of the right border of the heart (Fig. 4B). Aortography in the left anterior oblique view (Fig. 4C) revealed that the moderately dilated right coronary artery bent abruptly at the acute margin, causing the density seen in the right posterior oblique radiograph. Lateral and left posterior oblique chest radiographs showed no specific findings.

Differential Diagnosis

An enlarged right atrium, dilated ascending aorta, mediastinal tumor, or pericardial cyst can cast a rounded or angled shadow at the right border of the heart on the posteroanterior chest radiographs. The enlarged right atrium or dilated ascending aorta usually appears as a rounded right border of the heart in the right posterior oblique view. Mediastinal tumor or pericardial cyst often causes the right border of the heart to resemble a giant fistula in the right coronary artery on the posteroanterior radiograph (Fig. 5A). In the right posterior oblique view, however, the right border of the heart can be distinguished clearly from the silhouette of the mass (Fig. 5B).

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Self-Expanding Metal Stents for Palliative Treatment of Malignant Ureteral Obstruction

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OBJECTIVE. We studied the immediate and long-term efficacy of the Wallstent device in the treatment of ureteral obstruction caused by malignant disease.

SUBJECTS AND METHODS. In 23 patients (30 ureters), self-expanding metal stents were implanted endoscopically ($n = 23$), percutaneously ($n = 5$), or bidirectionally ($n = 2$) because of extrinsic malignant ureteral obstruction. Patients who met the following criteria were selected for stent implantation: (1) life expectancy of at least 6 months, (2) current polychemotherapy, (3) increasing levels of serum creatinine, and (4) severe clinical signs and symptoms associated with hydronephrosis. Obstruction was diagnosed by using sonography and excretory urography. After radiologic localization and dilatation of the stenosis, the Wallstent device was inserted. For 4 weeks, a double-J catheter inserted through the stent was kept in place in order to prevent obstruction by reversible hyperplastic reaction of the urothelium. Patients were followed up for 31 weeks (range, 3–75 weeks). Follow-up included sonography, excretory urography, and determination of serum levels of creatinine in all cases and furosemide scintigraphy and the Whitaker test in selected cases.

RESULTS. Implantation of the Wallstent device was successful in 30 (97%) of 31 cases attempted. The survival rate was 81% after 6 months and 61% after 8 months. The primary patency was 83% after 30 weeks. Complications were macrohematuria (one patient) and incrustation (two patients). No infection and no migration or compression of the stent were observed.

CONCLUSION. Implantation of a Wallstent device is a safe and effective alternative to double-J catheter placement in tumor-associated ureteral obstruction.

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Retroperitoneal lymph node metastases and primary tumors of the pelvis are common causes of extrinsic ureteral obstruction and hydronephrosis [1]. Surgical urinary diversion has been replaced by transcatheter techniques because the newer methods are easier to use and have far lower morbidity and mortality rates [2]. Two methods are now being used for palliative treatment of hydronephrosis caused by malignant compression of the ureter: percutaneous nephrostomy and implantation of a synthetic endoprosthesis. Neither method is entirely satisfactory. Nephrostomy is uncomfortable for the patient, and the overall complication rate is 4–5% [3, 4]; little information has been published on how long the ureteral double-J catheter remains patent. Docimo and Dewolf [5] reported that results were poor when indwelling silicone and polyurethane catheters were used. Excellent results have been reported by Cardella et al. [6], who used a urine-compatible polymer (C-Flex) stent, and by Rackson et al. [7], who used a biocompatible Percuflex stent. Implantation of self-expanding metal stents has been effective in the treatment of malignant obstruction of the bile ducts [8], urethral strictures [9–11], and benign prostatic hypertrophy [12]. The use of Wallstent devices to treat ureteral obstruction is a logical extension, even if reobstruction caused by urothelial hyperplasia is a possible outcome [10, 13]. We report the immediate and long-term efficacy of

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the self-expanding metallic Wallstent device in the treatment of ureteral obstruction caused by malignant retroperitoneal tumor.

Materials and Methods

Between April 1990 and March 1992, 30 ureteral obstructions were treated in 23 patients (16 women, seven men) by using a self-expanding metal stent. Obstruction was due to primary or secondary malignant tumors in all cases. The mean age of the patients was 62 years (range, 29–78 years), and the mean interval between diagnosis of primary disease and onset of hydronephrosis was 76 weeks (range, 0–468 weeks). In three patients, hydronephrosis was the first manifestation of the tumor; in one patient, hydronephrosis was caused by lymph node metastases from a breast carcinoma diagnosed 9 years earlier. The primary diseases were melanoma (one patient), colon carcinoma (four patients), rectal carcinoma (three patients), prostatic carcinoma (two patients), malignant lymphoma (one patient), breast carcinoma (one patient), uterine carcinoma (two patients), ovarian carcinoma (six patients), bladder carcinoma (one patient), and malignant mesothelioma (two patients). Only patients who met the following criteria were selected for stent implantation: (1) life expectancy of at least 6 months, (2) current polychemotherapy, (3) increasing levels of serum creatinine, and (4) severe clinical signs and symptoms associated with hydronephrosis.

If hydronephrosis was suspected on the basis of clinical findings, sonograms of the kidneys were obtained to confirm the diagnosis. Before stent implantation, ureteral obstruction was treated by placement of a 5-French double-pigtail catheter in nine cases and by percutaneous nephrostomy in 10 cases.

The stenosis was crossed by a guidewire inserted transurethrally and then by a 5-French cobra catheter. If access could not be gained in this way, the stenosis was crossed antegrade through a nephrostomy tract. The route of stent placement was antegrade in five cases, retrograde in 23 cases, and bidirectional in two cases. After placement of the guidewire, the stenosis was dilated by using an Olbert balloon catheter (Meadox Surgimed, Copenhagen, Denmark; length, 4 cm; diameter, 5 mm), thus creating enough space to insert the stent.

The Wallstent device (Medinvent, Lausanne, Switzerland) is made of elastic mesh, woven from stainless steel alloy filaments (0.08–0.10 mm). It is mounted on a 7-French catheter. The standard stents we used were 7 mm in diameter and 35 or 70 mm long when fully expanded. If longer segments had to be stented, two or three stents were placed in sequence with an overlap of at least 10 mm [14, 15]. The stent was 7 mm in diameter, the smallest diameter available. Use of stents with smaller diameters would make follow-up endoscopy difficult.

We observed severe obstruction caused by ureteral edema in our first three treated patients. For that reason, a polyurethane double-pigtail catheter was inserted through the lumen of the stent in all subsequent patients and kept in place for 4 weeks to prevent obstruction by urothelial hyperplastic reaction. Follow-up for all patients included sonography once a month, starting the day after stent implantation. Excretory urography was performed on the day after stent placement, after 4 weeks, after removal of the double-pigtail catheter, and at 2 and 6 months. If the patient had a percutaneous nephrostomy, antegrade pyelography was performed before the nephrostomy tube was removed. The Whitaker test and furosemide scintigraphy were performed in selected cases. Serum levels of creatinine were determined every month.

Results

Implantation of a Wallstent device was attempted in 31 ureters and was successful in 30 (97%). In one patient, a

totally obstructed ureter could not be recanalized. In some early cases, we could not cross the stenosis with the stent catheter until the area was dilated with a balloon catheter. In some patients, we could not pass a guidewire through the stenosis without ureteroscopic guidance. Immediately after stent implantation, the Wallstent device was expanded to 5–7 mm, and the flow of urine from the kidney to the bladder was uninhibited. The serum level of creatinine was significantly elevated in six patients before implantation; it returned to normal in five patients within 1 week after the stent was in place.

Placement of additional Wallstent devices was necessary because of tumor progression ($n = 3$) and radiation stenosis distal to the stent ($n = 1$). In five patients, an additional double-pigtail catheter was necessary because of tumor ingrowth (one patient) or delayed hyperplastic reaction of the urothelium (four patients).

Macrohematuria occurred in one patient on the first day after stent implantation, but stopped spontaneously when the double-pigtail catheter was removed. In two ureters, incrustations had developed after 30 weeks; the incrustations were removed endoscopically in these cases. No dislocation of the stent, no tumor compression, and no infection occurred.

The mean follow-up time was 31 weeks (range, 3–75 weeks). Eight patients died during the follow-up period. Survival, according to life-table analysis, with the time of Wallstent implantation used as the starting point, was 81% after 6 months and 61% after 8 months. The primary patency [16] (patency that ends when any procedure that might preserve or extend patency is performed) was 83% after 30 weeks (Fig. 1). Autopsy was performed on three of the eight patients who died. Hydronephrosis was not observed in any of these patients. One patient had early ingrowth of prostatic carcinoma, which did not cause obstruction. In the group of patients who are still alive, 13 have no evidence of hydronephrosis (Fig. 2). In two patients, hydronephrosis due to extensive tumor growth distal to the stent developed.

Uroepithelial thickening was evaluated in our first patients

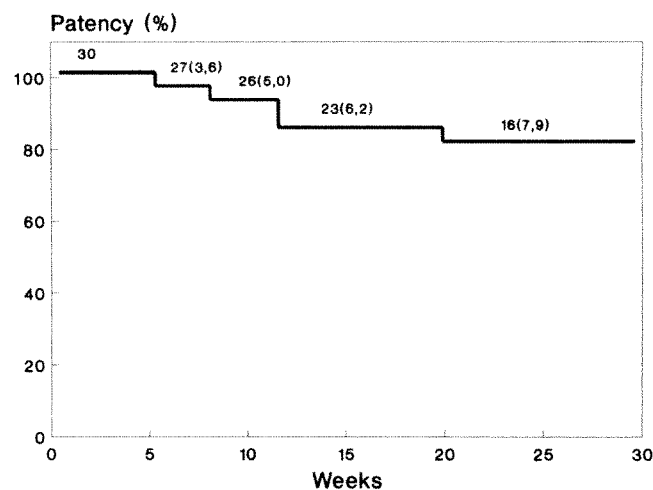


Fig. 1.—Graph shows percent primary patency of Wallstent devices by number of weeks after implantation in palliative treatment of malignant ureteral obstruction. Numbers on graph ($n = 30$) indicate the number of stents at risk; standard errors are in parentheses.

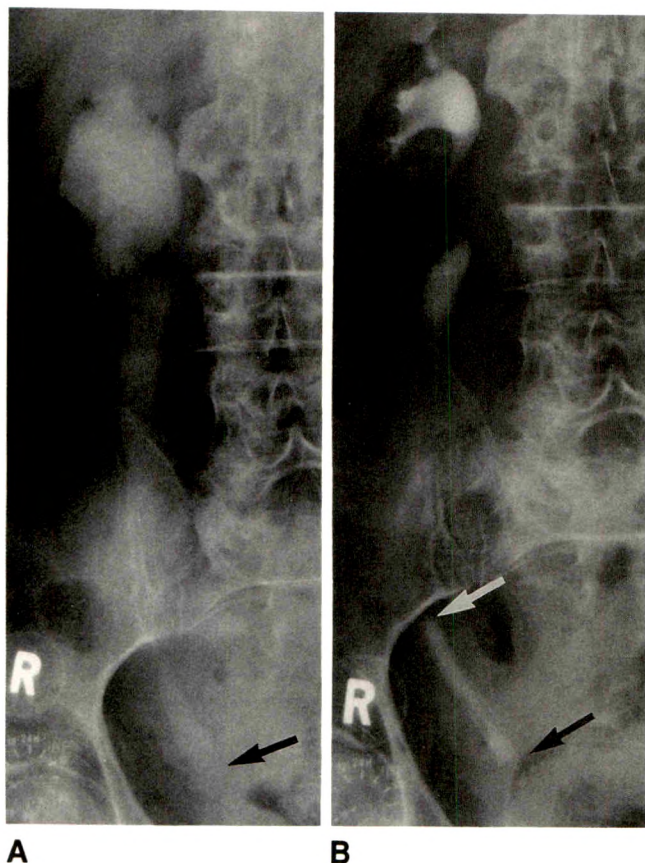


Fig. 2.—**A**, Excretory urogram shows obstruction (arrow) and dilatation of right ureter caused by a malignant tumor in pelvis.
B, Excretory urogram obtained 2 months after metal stent (arrows) was implanted on right side shows normal function of right kidney.

in whom we did not routinely insert a double-pigtail catheter immediately after implantation. In these patients, antegrade pyelography through a nephrostomy tube showed high-grade or complete obstruction within the stent lumen (Fig. 3), which was confirmed endoscopically. Later in our study, excretory urograms obtained 1 day after stent placement showed hyperplastic reaction of the urothelium in all patients. Some evidence of hyperplastic urothelium after 4 weeks was found, but flow of urine was not inhibited.

Discussion

Palliative treatment of ureteral obstruction caused by malignant tumors can be accomplished by surgical diversion, percutaneous nephrostomy, or implantation of a synthetic endoprosthesis. Wallstent devices may solve a number of problems associated with these methods. The reasons for the failure rate of internal stents in the face of extrinsic obstruction are not known. It may be related to ureteral peristalsis, venting side holes, or the urinary flow rate [5].

The theoretical benefits of a Wallstent device in the ureter are (1) its potential incorporation into the ureteric wall, which should prevent migration, incrustation, infection, or hematuria, as seen with double-pigtail catheters [17]; (2) a longer duration of patency compared with that of double-J catheters; and (3) physiologic urine flow to the bladder.

The limitations of using the Wallstent device in the ureter are related to the phenomenon of a hyperplastic urothelial response, as seen in the urethra and bile ducts [10, 11, 13]. Tumor ingrowth is a second potential limitation, although we observed this in only one of our patients. By creating a rigid tube within the ureter, the Wallstent device interferes with

Fig. 3.—Antegrade pyelograms obtained 1 day after stent implantation show obstruction due to edema of urothelium within stent lumen.

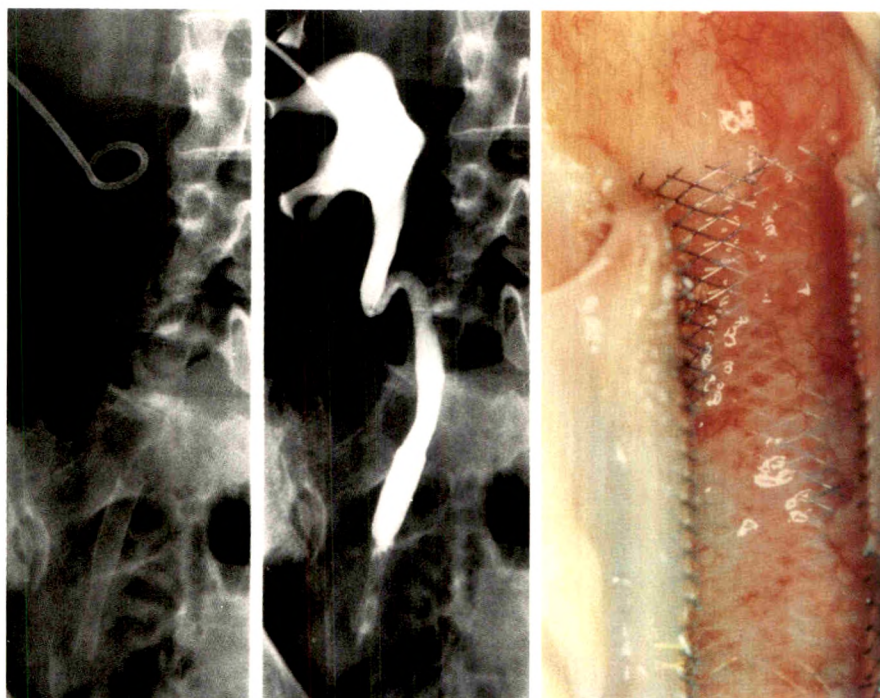


Fig. 4.—Photograph of autopsy specimen shows Wallstent device incorporated in ureteral wall.

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peristalsis, although continuous peristaltic movement from the kidney to the bladder is not severely inhibited.

The long-term results are satisfactory when patency rates are compared with survival rates. Patency is better with the Wallstent device than with polyurethane and silicone double-J catheters [5]. When other indwelling double-J catheters, such as the urine-compatible polymer (C-Flex) or Percuflex stents, are considered, the patency with the Wallstent device is comparable [6, 7, 18].

The thickening of the urothelium, which we noted on the first day after stent implantation, is thought to reflect edema of the ureteral wall. Reversible hyperplastic proliferation of the urothelium after denudation of the bladder has been described in an animal model [19]. This phenomenon may have occurred during the first weeks after stent implantation in the patients in our series. Placement of a double-pigtail catheter will maintain patency until the metal stent is completely incorporated and thickening of the urothelium has resolved.

A lining of urothelium is present along the Wallstent device after at least 8 weeks, as we observed endoscopically in five patients and at autopsy in one patient (Fig. 4). A completely incorporated stent should prevent incrustation, infection, or mechanical damage to the urothelium, which can occur with indwelling catheters [17]. Optimal incorporation of the stent requires complete apposition of the stent to the inner wall of the ureter.

The effect of stent placement on peristalsis is not clear. Djurhuus et al. [20] stated that ureteric peristalsis is not required for normal ureteral function. After stenting one ureter along its entire length, we observed normal function on the excretory urogram, in accord with their observations. The Whitaker test, performed in some cases, showed no increased pressure in the renal pelvis or in the upper ureter.

As no major complications occurred, and hydronephrosis could be prevented in most of the patients during the observation period, we conclude that the implantation of a Wallstent device is a safe and effective method for the palliative treatment of tumor-associated hydronephrosis. The double-J endoprosthesis still remains the treatment of choice in this group of patients. In case of stent failure, placement of a Wallstent device is recommended as an alternative procedure.

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Needle-Tip Localization During CT-Guided Abdominal Biopsy: Comparison of Conventional and Spiral CT

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OBJECTIVE. This study was performed to determine whether the time required for needle-tip localization during biopsy of the abdomen would be reduced if continuous-volume data acquisition, also known as spiral CT, were used for guidance instead of conventional CT.

SUBJECTS AND METHODS. Forty patients had biopsies of an abdominal mass; half underwent needle-tip localizations with conventional CT and half with spiral CT. The times required to localize the needle for 104 needle passes were calculated; scanning and reconstruction times were included, and the radiologist's technique and procedural difficulties were deliberately excluded. The mean needle localization times with conventional and spiral CT were compared for the upper abdominal and pelvic regions by using the two-tailed unpaired Student's *t*-test.

RESULTS. The mean time ($\pm$ SE) for spiral CT was 35 ± 2 sec compared with 105 ± 18 sec for conventional CT ($p < .001$). When analyzed by region, times with spiral CT were shorter in both the upper abdomen (means, 37 sec for spiral CT vs 150 sec for conventional CT, $p < .001$) and pelvis (means, 25 sec for spiral CT vs 74 sec for conventional CT, $p = .038$); the magnitude of the improvement was greater in the upper abdomen.

CONCLUSION. The time required to find the needle tip during guided biopsy of an abdominal mass is reduced with spiral CT compared with conventional CT. This improvement is partly a result of the ability to eliminate respiratory misregistration with spiral CT, which is not possible with conventional multisectioal CT; hence the greater advantage in upper abdominal biopsy.

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The usefulness of CT-guided percutaneous aspiration and biopsy has been widely reported [1-8]. The principal advantage of CT guidance has been the ability to position and locate the needle tip precisely, an important step in the successful sampling of all lesions [8-11]. Conventional multisectioal CT, which consists of individual scans obtained during separate breath-holds, can be limited by respiratory misregistration, which prevents consistent contiguous scanning. Respiratory misregistration occurs because tidal volumes vary between respiratory cycles, and despite careful instructions, some patients do not end each breath at the same level. This results in "skip" areas in the imaged organ or lesion, and consequently the needle tip may not be imaged during a conventional multisectioal CT sequence. Because of respiratory misregistration, precise visualization of the needle tip can be a time-consuming procedure requiring multiple scans.

Spiral CT uses a continuously rotating detector system and continuous feeding of the CT table through the scanner such that data are acquired during a single breath-hold, and subsequently reconstructed at selected section intervals. The resulting images are truly contiguous, free of gaps or overlapping sections caused by respiratory misregistration [12]. We hypothesized that use of spiral CT would reduce the time required to localize the needle tip compared with that needed for

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conventional CT during CT-guided biopsy of abdominal masses.

Subjects and Methods

Of 40 patients undergoing CT-guided biopsy of abdominal masses, conventional CT was used to localize the needle tip in half the patients and spiral CT was used in the other half. All biopsies were performed by using the Siemens Somatom Plus CT scanner (Siemens Medical Systems, Iselin, NJ). Our usual routine method (with conventional CT) was to obtain individual scans, await the result, and then decide if additional scans were required. The localization protocol for conventional CT consisted of individual scans (10 × 10 mm sequence, 2-sec exposure, 120 kVp, 210 mA) beginning at the suspected location of the needle tip within the patient; scans were repeated until the needle tip was visualized. The localization protocol for spiral CT consisted of a 10-mm-thick volumetric data acquisition (120 kVp, 165 mA) obtained with a table feed rate of 10 mm/sec and beginning 1 cm above the estimated location of the needle tip within the patient. During a 5-sec exposure a total volume of 5 cm was scanned during a single breath-hold. Images were then reconstructed by using a 10-mm slice thickness and 10-mm intervals; the first and last slices were discarded, yielding a 3-cm volume of imaged tissue. The interventional radiology team (including a staff radiologist and a resident or fellow) aligned the scan sections for both groups by using the localizer light and was instructed to repeat the scan or scan sequences until the needle tip, as indicated by the low-attenuation beam-hardening artifact, was detected [8].

The time required to localize the needle, defined as the interval between when the technologist begins the scan and the radiologist views the needle tip, was calculated for 104 needle placements in the 40 patients. The time for each conventional CT sequence included a 3-sec start-up delay, 2 sec for the first scan, the time between the first localization image and the image showing the needle tip (which includes scanning times for the remainder of the images and reconstruction times for all but the final image showing the needle tip), and the reconstruction time for the last image (8 sec). The time for each spiral sequence included a 3-sec start-up delay, a 5-sec scan time, and a time determined by the number of images necessary to visualize the needle tip multiplied by 11 sec (the reconstruction time, per image, of the software for this spiral CT scanner). The time determination deliberately excludes operator technique and lesion size and location, which generally determine the number of needle passes. It also excludes variables such as the skill of the technologist and the medical condition of the patient.

Data were analyzed by dividing the biopsies into two groups: those in the "upper abdomen," including the liver, spleen, adrenal gland, kidney, and pancreas, and those in the "pelvis," including pelvic masses as well as retroperitoneal lymph nodes. These assignments, although admittedly arbitrary, are based on the hypothesis that respiratory misregistration is greater during biopsies of the upper abdominal organs than during biopsies of pelvic organs and retroperitoneal lymph nodes, where little or no respiratory misregistration should occur. Mean needle localization times with conventional and spiral CT were compared for each organ and abdominal region by using the two-tailed unpaired Student's *t*-test.

Results

Table 1 summarizes the times required for needle-tip localization with the two techniques in 104 needle placements. The overall mean time ($\pm$ SE) for spiral CT was 35 ± 2 sec ($n = 62$) compared with 105 ± 18 sec ($n = 42$) for conventional

CT ($p < .001$). The use of spiral CT shortened the time required for needle localizations in biopsies of upper abdominal masses (mean time for spiral CT, 37 sec; mean time for conventional CT, 150 sec) and biopsies of masses in the pelvic organs and of retroperitoneal lymph nodes (mean time for spiral CT, 25 sec; mean time for conventional CT, 74 sec). The improvement accorded by using spiral CT was greater in the upper abdomen group than in the retroperitoneum/pelvis group. When spiral CT was used, upper abdominal needle-tip localizations took an average of only 12 sec longer than those in the pelvis, but there was still a statistically significant difference between the two regions ($p = .001$). With conventional CT, the time required for localization of the needle tip was longer for masses in the upper abdomen than for pelvic masses or retroperitoneal lymph nodes.

Discussion

Compared with sonography or fluoroscopy, disadvantages of CT-guided abdominal biopsy include its cost, availability, and procedure length. The accessibility of the lesion and the radiologist's skill are important determinants of overall procedure times. In addition, biopsy with conventional CT requires intermittent imaging between needle manipulations, a disadvantage not associated with real-time sonography or fluoroscopy. The results of our study suggest that continuous-volume data acquisition, although it does not eliminate the need to image the needle after placement, reduces the time needed to perform this step compared with conventional CT. The average amount of time saved by using spiral CT was approximately 70 sec for each needle placement. There are several reasons for this improvement.

In conventional CT-guided biopsies of organs in the upper abdomen, where respiratory misregistration may be significant, the times required for needle localization were longer than those for biopsies of pelvic organs or retroperitoneal lymph nodes. Elimination of respiratory misregistration prob-

TABLE 1: Needle Localization Times During CT-Guided Abdominal Biopsy

Area	Mean No. of Sec $\pm$ SE (No. of Needle Placements)		<i>p</i> Value
	Conventional CT	Spiral CT	
Upper abdomen			
Liver	163 $\pm$ 54 (7)	40 $\pm$ 4 (11)	.011
Kidney	—	41 $\pm$ 8 (4)	
Adrenal gland	179 $\pm$ 61 (7)	37 $\pm$ 2 (26)	<.001
Pancreas	51 $\pm$ 10 (3)	39 $\pm$ 4 (5)	.237
Spleen	—	19 $\pm$ 0 (2)	
Average (total)	150 $\pm$ 34 (17)	37 $\pm$ 2 (48)	<.001
Pelvis	74 $\pm$ 17 (25)	25 $\pm$ 2 (14)	.038
Overall average (total)	105 $\pm$ 18 (42)	35 $\pm$ 2 (62)	<.001

Note.—No needle passes of the kidney or spleen were done with conventional CT guidance. The pelvis includes pelvic masses and retroperitoneal lymph nodes. *p* values were determined by using two-tailed unpaired Student's *t*-test.

ably explains why the difference in times for these two regions was largely eliminated with spiral CT localization. In the pelvis, where no respiratory variation is expected, the mean time required for localization of the needle tip was shorter with spiral CT than with conventional CT by an average of 49 sec. Because a larger volume of tissue can be sampled (in a relatively short time) with spiral CT, the probability of localizing the needle tip is increased. This might also explain why the greatest average time saved was in the adrenal gland, where angling of the needle out of the axial plane is often required to avoid transgressing the pleural space. The larger standard errors with conventional CT localization are indicative of the wide range of times required to identify the needle tip, which is reduced with spiral CT.

However, a statistically significant difference in time for localization still existed between the upper abdomen and the pelvis when spiral CT was used. We can only speculate that this difference may be due to factors unrelated to respiration or scanned volume.

Although the study design, which examined only the time required for the needle localization, deliberately excluded confounding variables that would affect the overall time needed to perform a biopsy (radiologist's technique and procedural difficulty), some variability in the starting point of the initial scan may have occurred. This may have affected the time required for needle localization (favorably or unfavorably) in some of the needle passes, particularly if the needle was angled out of the axial plane. It is likely, however, that these factors were equally prevalent in both groups. An experienced interventional radiologist might argue that conventional CT often requires only a single scan to localize the needle tip, particularly in those cases in which the needle is completely within the axial plane. However, single-section localization occurred in only seven of 42 conventional needle localizations. Furthermore, the mean time with conventional CT was still greater than the time with spiral CT. Finally, the study design might be weighted against conventional multisectioal CT in that a better test of spiral CT per se might have been to conduct the conventional CT part of the study by using a series of four dynamically acquired scans. In fact, a dynamic series of four scans (120 kVp, 210 mA, 1-sec exposure, 3.5-sec cycle time) requires approximately 33 sec (average time based on three experiments on the same scanner), which is comparable to the time required with spiral CT. However, as stated in the Subjects and Methods section, this was not our routine in the past. This dynamic series would include a 15-sec actual exposure time during which a patient could sustain

a breath-hold—perhaps an attractive alternative to spiral CT if this technology were not available.

In conclusion, spiral CT reduces the time required to localize the needle tip in CT-guided biopsies and may reduce overall procedure times. Spiral CT reduces the time required to find the needle tip by rapidly imaging a larger volume of tissue and by eliminating respiratory misregistration. This technique could be used in all CT-guided interventions (biopsies, fluid aspirations, and drainages) throughout the body and should be most helpful when the target organ moves with respiration. Needle-tip localization is only one (perhaps small) component of a CT-guided biopsy, so the impact of improving needle-tip localization may not significantly shorten overall procedure times in some cases.

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Martin W. Donner, 1920–1992



Martin Donner passed away April 13, 1992, after a long illness that had necessitated hospitalization from July 1991 until his death. He received a heart transplant on March 6, 1992, but complications both before and after transplantation resulted in gradual deterioration and ultimately death. He is survived, in Baltimore, by his wife of 41 years, the former Adelheid (Heidi) Wimmer; a son, Thomas; two daughters, Cornelia and Stephanie; a son-in-law, Stephen McClain; and a grandson, Nicholas. He also leaves behind a brother, Arndt, in Hamburg, Germany.

Martin Donner was born in Leipzig, Germany, on September 5, 1920. He trained in medicine at the University of Leipzig from 1939 to 1945. After graduation, he completed 6 years in internal medicine before entering a residency in radiology, of which 1 year was spent in Bonn and 3 years in Cologne. He migrated to the United States in 1954 at the age of 34 and spent the next 3 years in St. Petersburg, FL, at Mount Park Hospital. There he completed three 1-year residencies—in radiology, general practice, and internal medicine; he was chief resident in internal medicine. In 1957, he and his family relocated to Baltimore, MD, where he became assistant resident and fellow in radiology at Johns Hopkins Hospital. Over the next 20 years, Martin gradually progressed up the academic ladder, becoming a professor of radiology in the School of Medicine and professor of radiological science in the School of Hygiene and Public Health in 1966. Between 1967 and 1973, he was radiologist-in-charge of the diagnostic division. In 1971, after an extensive international search, Martin was appointed chairman of the Department of Radiology and Radiological Science.

At this time he was also director of the Department of Radiology of the Good Samaritan Hospital and a consultant to the Veterans Administration Hospitals and the Rosewood State Hospitals in Maryland. He also served as a special consultant to the National Institutes of Health, the Maryland Academy of Science, and The Johns Hopkins Applied Physics Laboratory. He was named chairman of the Scientific Advisory Board of the Institute for Diagnostic Research at the Free University of Berlin in 1990 and Distinguished Service Professor of The Johns Hopkins University in 1992.

During Martin's 15 years as chairman of the Department of Radiology and Radiological Science at Johns Hopkins, the department grew dramatically in number of staff and space. He recognized and stressed the importance of technological advances, expanding the department to include newer technologies such as sonography, positron emission tomography, digital subtraction angiography, CT, MR imaging, and MR spectroscopy. Interventional radiology also grew dramatically in size and scope during his tenure. Another important departmental contribution was the development of the concept and the building of a central film viewing area that contained all the inpatient films with their comparison films. Until that time, comparison films often could not be located because films were scattered around the hospital in different locations. Martin was convinced of the value of the radiologist as a consultant; the radiologist on duty in the central viewing area served in that function, advising specialists in other fields on the relative merits of various imaging procedures.

Martin was especially proud of the formation of the first endowed professorship in his honor, dedicated in 1991. William Brody was named the first Martin W. Donner Chair of the Russell H. Morgan Department.

Possibly the most far-reaching achievement, however, came with the formation of a multidisciplinary research and clinical facility to study and treat patients with swallowing disorders. In collaboration with others such as James Bosma, and Arthur Siebens from the Good Samaritan Hospital, a multidisciplinary group was formed whose efforts culminated in the opening in 1981 of the first swallowing center in the country. The center stands as a model for other such centers in the United States and around the world.

Martin served as its director from 1981 to 1989. He stepped down from the chairmanship of the Radiology Department in 1987.

Martin had long seen the need for education and communication about patients with swallowing disorders. Apart from many other publications on dysphagia, he was especially proud of the so-called special issue, a 68-page special section on the diagnosis and treatment of swallowing disorders written by the members of the swallowing center and published in *Gastrointestinal Radiology* in 1985. In January 1986, he became the editor-in-chief of a new international journal, *Dysphagia*, a multidisciplinary journal focusing on swallowing disorders. A recent book, edited by Jones and Donner, presents a state-of-the-art approach to imaging patients who have dysphagia.

His contributions to education and research were wide ranging. He was the author or coauthor of more than 150 publications, many of them on dysphagia, but others that reflect a diverse number of interests. He had been visiting professor to more than 45 institutions both in the United States and overseas. Before assuming the chairmanship of the department, his primary research interests involved the imaging aspects of gastrointestinal function and the effect of pharmacologic agents on gastrointestinal function. He had also been interested in placental blood flow and was the coauthor of a book on the placenta. In 1971, he was a founding member of the Society of Gastrointestinal Radiologists. He served as the president of the society in 1978–1979 and was awarded the Cannon Medal, the society's highest honor, in 1983. He has received recognition from societies in several other countries, including Sweden and Germany.

On a personal note, Martin loved the cultural aspects of life, such as music, literature, and art, as well as the physical, such as good food and wine. His passion was tennis, which he played skillfully and often until early last year when heart trouble set in.

Martin will be sorely missed by all whose lives he touched. His insight, vision, and breadth of knowledge were well known, as was his sensitivity, thoughtfulness, and tact. I will miss him deeply as a caring and nurturing mentor, as well as a valued colleague and friend. He was a unique person, a true Renaissance man.

Bronwyn Jones
Baltimore, MD 21287

Case Report

Iodide Mumps Due to Low-Osmolality Contrast Material

Howard L. Berman¹ and Vera Delaney²

Swelling of the submandibular, sublingual, and parotid salivary glands is an uncommon complication associated with intravascular administration of contrast material. This reaction was called "iodide mumps" by Sussman and Miller [1] in 1956, although earlier cases had been reported [2, 3]. A search of the recent medical literature showed that since 1973, only three reports [4–6] of iodide mumps have been published. In a review of the information on package inserts for contrast material from four major pharmaceutical manufacturers (Squibb, Berlex, Mallinckrodt, and Winthrop), we found that only one company, Winthrop, mentioned swelling of the salivary glands as a possible adverse reaction to iodinated contrast material. All reported cases in the English-language literature have been due to the intravascular injection of ionic contrast material. Inasmuch as not one of these cases was caused by low-osmolality contrast material, it might be concluded that the use of low-osmolality agents could eliminate the risk of iodide mumps. We therefore report a case of iodide mumps due to low-osmolality contrast material to show that such a conclusion would be erroneous.

Case Report

A 62-year-old man with end-stage renal disease associated with glomerulonephritis whose treatment included thrice weekly hemodialysis had an elective cerebral arteriogram. It had been discovered earlier that he had a carotid bruit due to severe stenosis of the left internal carotid artery (visualized by duplex Doppler sonography). Because 13 years earlier he had had a rash and mild tongue swelling after injection of contrast material, the patient was pretreated with

three doses of oral prednisone given during the 18-hr period before the procedure as well as diphenhydramine given IV immediately before the examination. The arteriogram showed a 95% focal stenosis of the left internal carotid artery, which was the sole blood supply to the left middle cerebral artery. During the arteriogram, the patient received 100 ml of low-osmolality contrast material: 60 ml of iohexol 350 mg I/ml (Omnipaque 350, Winthrop Pharmaceuticals, New York, NY) and 40 ml of iohexol 300 mg I/ml (Omnipaque 300). The patient was asymptomatic during the procedure and the initial period afterward. The next morning, 24 hr after the arteriography, he complained of tenderness and progressive swelling of the parotid, submandibular, and sublingual glands. In addition, he had conjunctival edema and erythema associated with painful enlargement of the lacrimal glands. The thyroid gland was also tender and swollen, although less so than the salivary glands. No evidence of laryngeal edema or bronchospasm was apparent, and the tongue was not involved. The patient was given diphenhydramine intramuscularly and hydrocortisone IV, but the drugs had no effect. The patient then went for his regularly scheduled hemodialysis. During the 4-hr dialysis session, his condition stabilized and then improved rapidly. The patient was discharged the next day.

Discussion

Iodide mumps is part of a continuum of signs and symptoms due to excessive intake or injection of iodine and iodine-containing compounds. This is known as iodism and includes inflammatory swelling of the salivary glands, coryza, skin rashes, and other more severe systemic reactions [7]. Salivary and lacrimal gland swelling is caused in part by the ability of these glands to collect and concentrate high levels of

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inorganic iodide [8]. The high concentration of iodide appears to cause inflammation of the glands [4]. Although free inorganic iodide is known to be present in small amounts in radiographic contrast material [9], not enough is present to explain the high concentration found in the saliva of patients with iodide mumps. Talner et al. [10] suggested that the inorganic iodide found in the saliva was actually split off from the contrast molecule by the body. The amount of inorganic iodide present depends on the quantity of contrast material given and the body's ability to excrete it. It is not surprising that most cases occur in patients with compromised renal function. Reduced renal excretion of contrast material results in increased in vivo liberation of iodide and enables the salivary glands to concentrate inorganic iodide during an extended period. This would explain the often late onset of signs and symptoms, up to 48 hr after administration of contrast material.

Current treatment for iodide mumps is supportive therapy and the administration of antiinflammatory agents [2, 3]. For patients who do not respond, such as in this case, use of dialysis to reduce blood levels of contrast material and iodide may be worthwhile. In our patient, iodide mumps did not occur after an earlier peripheral arteriogram. Similar premedications and low-osmolality contrast material were given. The major difference between the two examinations was the completion of hemodialysis immediately after the first arteriogram.

To our knowledge, this is the first reported case in the English-language literature of iodide mumps due to low-osmolality contrast material. It is especially significant because the patient was pretreated with prednisone before the contrast material was administered. The only other reported case of iodide mumps due to low-osmolality contrast material we could find is in an Italian journal [6]. In that case, swelling of the salivary glands developed in a patient with chronic renal

failure, after the administration of 160 ml of low-osmolality contrast material (iohexol, 300 mg I/ml).

Iodide mumps does not appear to be an allergic reaction to iodinated contrast media. More likely, it is an inflammatory response to inorganic iodide produced from elevated blood levels of contrast material, especially in patients with compromised renal function [9]. The administration of low-osmolality contrast material even when combined with prophylactic treatment with corticosteroids does not eliminate the risk of iodide mumps, and patients with renal failure who have iodism may benefit from early hemodialysis.

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Digital Archive Center: Implementation for a Radiology Department

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OBJECTIVE. In this article, we describe the implementation of a digital archive center for a radiology department in a 700-bed teaching hospital.

MATERIALS AND METHODS. The archive center consists of two identical archive systems, each comprising five components: an archive server, a data-base server, an optical disk library, a stand-alone optical disk drive, and a communication network. An image management system controls the image traffic from acquisition devices to display stations. A fault-tolerant mechanism was built into the archive center to achieve a 100% uptime.

RESULTS. The center has been in operation for over 6 months. We have not experienced a single total system failure during this period. It currently archives all digital images from three MR units and four CT scanners and selected images from three computed radiographic systems and two laser film digitizers. The center archives between 1.5 and 2.0 gigabytes of images per workday.

CONCLUSION. With its built-in fault-tolerant mechanism, we believe that the implemented archive center is very reliable and is suitable for a radiology department to archive its digital images.

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Optical disk storage for archiving medical images was suggested in 1986 [1]. We developed a prototype optical library system for radiologic images in 1988 [2]. Following this development, we planned a staged implementation of a picture archiving and communication system (PACS) for clinical use [3]. Each new digital imaging system implemented in an individual diagnostic radiology section of the department constitutes an acquisition component of the PACS. In October 1990, we successfully installed a fiber-optic communication network connecting the inpatient facility in the Center for Health Sciences with the outpatient facility in the Medical Plaza that provides a fast and efficient image communication among the PACS components located at different sites [4]. Images acquired from different digital imaging systems in the department are transferred to an archive center, where they are archived on optical disks and distributed to remote display stations. The intent of using a centralized PACS image management system is to provide intersectional referencing among the inpatient and outpatient facilities throughout the entire radiology department [5]. Automation and reliability become dominant factors in determining whether an archive system services the clinic satisfactorily. Our primary goal is to implement a dual archive system for automatic archiving of digital images from various radiologic imaging devices and to minimize the generic problems such as hardware failure, power outage, and network traffic that will either interrupt the operation or degrade the performance of an archival system in PACS. By following these guidelines, we have developed an automated archive system that promises no loss of images and 24-hr on-line service.

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Materials and Methods

Systems Configuration

Our PACS consists of five classes of computers connected by various networks: radiologic imaging systems, acquisition nodes, archive servers, data-base servers, and display workstations. The digital archive center is configured with two identical archive systems, each comprising five components: an archive server, a data-base server, an optical disk library, a stand-alone optical disk drive, and a multiple communication network.

The archive server.—A Sun SPARCserver 490 computer (Sun Microsystems, Mountain View, CA) specified at 22.6 million instructions per second is used as an archive server, from which an optical disk library and a stand-alone optical disk drive are attached. Images acquired from radiologic imaging devices are transferred from acquisition nodes to one of the two archive servers and are archived on optical disks. In addition to its primary function of archiving images, an archive server also acts as a PACS controller that directs the routing of all incoming images to various destinations such as display stations or the print station. Each archive server has four 1-gigabyte intelligent peripheral interface (IPI) disks attached, capable of storing almost 1 week's worth of images acquired from different imaging systems including three MR units, four CT scanners, three computed radiographic systems, and two laser film scanners. On an average, 210 MR, 140 CT, and 130 computed radiographic examinations are temporarily stored in an archive server. The average sizes of the MR, CT, and computed radiographic examinations are 1.92, 12.6, and 6.5 megabytes, respectively. This local storage provides a fast retrieval of recent images from the high-performance IPI disks instead of the optical disks.

The data-base server.—A Sun SPARCserver 490 computer with two 1-gigabyte IPI disks is used as a data-base server with the Sybase SQL utilities (Sybase Inc., Emeryville, CA) to manage all the acquired images and related patient information [6]. The Sybase is interfaced with the departmental radiology information system (MAX-IFILE, DMI, Inc., Minneapolis, MN), which provides the archive center with patient information. A prefetching and preloading algorithm has been developed to fetch images of the most recent examination of the current patient. The prefetched images are transmitted to the display station along with those from the current examination. Users can also request images from earlier examinations at the display station by entering the patient's identification number.

The optical disk library.—The Kodak ADL 6800 Optical Disk Library (Eastman Kodak Co., Rochester, NY) consists of two optical disk drives and one disk controller, which provides a storage capacity of 680 gigabytes. The library can hold up to 100 optical disks, each offering a capacity of 6.8 gigabytes. Two types of data interface are used for establishing communication between the optical library and its Sun host computer: an RS-232 interface for command transfer and the Small Computer Systems Interface for data transfer. The average on-line clinical archival and retrieval rates are 260 and 400 kilobytes/sec, respectively.

The stand-alone optical disk drive.—The Kodak stand-alone optical disk drive operates a single 6.8-gigabyte optical disk and is designated for retrieving images on an urgent-need basis. In the event of hardware failure of an optical library, an optical disk can be unloaded manually from the malfunctioning library and fed into the stand-alone optical drive so that requested images are retrieved from the optical disk and sent to the requested display station or print station.

The multiple communication networks.—Our intent in using multiple networks for image communication is to provide independent data paths so that individual networks of different bandwidths can carry on the transfer of images according to different levels of needs of the various PACS components [7–10]. Three types of network interfaces are installed in the archive servers: Ethernet, Fiber Distributed

Data Interface (FDDI), and UltraNet (Ultra Network Technologies, San Jose, CA).

The low-cost standard Ethernet networking components are used for connecting CT, MR, and computed radiographic systems to the acquisition nodes [11], as well as for interconnecting all PACS components and serving as a backup for the FDDI and UltraNet networks. The Ethernet network is specified at a bandwidth of 10 megabits/sec (1.25 megabytes/sec) and can achieve a throughput of 400 kilobytes/sec by using a queuing control mechanism in the archive server.

The 100-megabit/sec FDDI network is designated for transmitting data from the acquisition computers to the archive servers. This network operates at a throughput of 900 kilobytes/sec, which is almost three times as fast as the Ethernet network. This faster network capacity results in a shorter residence time for the acquired images on local disks of the acquisition computers.

The 1-gigabit/sec fiber-optic UltraNet network is used for distributing images and patient information from the archive servers and data-base servers to the display stations. The UltraNet network operates at a throughput of 1.2 megabytes/sec, and less than 10% degradation is observed while multiple transmissions are taking place simultaneously. Two UltraNet hubs, one each at the Center for Health Sciences and the Medical Plaza, are interconnected over the inter-building fibers. This constitutes an integrated high-speed network providing the radiologists and referring physicians in the clinic with images for primary diagnosis and consultation with minimal delay. Figure 1 is a block diagram showing the configuration of the archive systems in the Center for Health Sciences and in the Medical Plaza.

All of the throughputs for the three networking systems were disk-to-disk average throughputs measured from our clinical PACS communication networks while multiple transmissions were taking place [7, 8]. It is obvious that disk-to-disk transfer is limited by disk input/output speed. For memory-to-memory transfer, the FDDI and the UltraNet networks can reach 1.8 and 5 megabytes/sec, respectively.

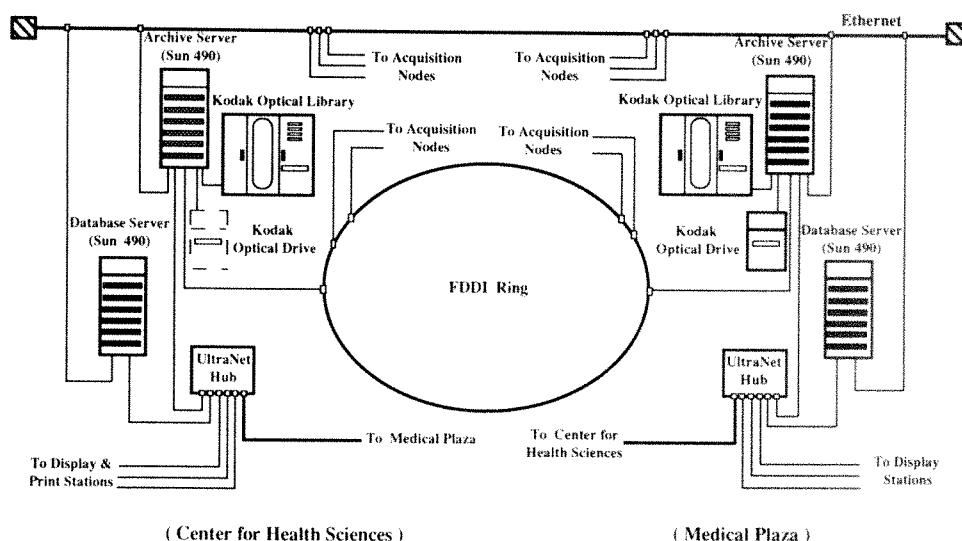
Image Retrieval

Image retrieval takes place at the display station. Attached to the archive center through the communication networks are 1K (three monitors) and 2K (two monitors) display stations. The 1K station is equipped with a 1-gigabyte magnetic disk, whereas the 2K station has a 2.6-gigabyte parallel-transfer magnetic disk for local image storage. The text monitor at the display station shows a patient directory and an examination directory (Fig. 2A). The user selects the patient whose images are to be reviewed from the patient directory by using a cursor. Descriptions of all images of the patient currently residing in the magnetic disk are shown in the examination directory. The user can select any image or a set of images to be displayed by clicking the cursor. The average time to display a 1K image on the 1K station, or a 2K image on the 2K station, is less than 2 sec. To retrieve images that are not in the magnetic disk, the user can use the retrieval function shown in Figure 2A, lower right. Once activated, a complete examination history directory of the patient is shown (Fig. 2B). The user can select any number of images from the archive center by moving the cursor to the box. As an example, the time required from the request to the display is about 1–3 min for a 20-megabyte CT examination.

Fault Tolerance

A high percentage system uptime is important when a PACS is in clinical operation [12]. As the major component in PACS that controls all data flows from acquisition to archive to display, an archive server must guarantee 24-hr on-line service with no interruption. The following is a description of the fault-tolerant mechanism implemented in our archive center to handle any malfunctioning components of the dual-configured archive systems.

Fig. 1.—Systems configuration in Center for Health Sciences (inpatient facility) and Medical Plaza (outpatient facility). On each site, a Sun SPARC-server 490 computer connected to a Kodak optical library and a Kodak optical drive serves as an archive server, global Ethernet network interconnects all PACS components, Fiber Distributed Data Interface (FDDI) network connects the archive server to acquisition nodes, and high-speed UltraNet network connects the archive server and data-base server to display stations, providing fast image display. All three of the communication networks are connected from one facility to another via the interbuilding optical fibers.



Patient Directory		
1. Adams, Alison	01/09/92	CR Port CXR
2. Bazan, Sean	01/09/92	CT L-Spine
3. Caswell, William	01/10/92	CT Brain
4. Costa, David	01/16/92	CT L-Spine
5. Edwards, Anthony	01/11/92	CR Chest
6. Fry, Edmund	01/08/92	CR Chest
...		
...		
...		

Patient Demographic Information	
Costa, David	123-45-67
24-Nov-1945	Male

Examination Directory	
01/16/92 13:15	Head CT L-Spine (Std Axial)
01/16/92 13:15	Head CT L-Spine (Scout)
01/13/92 11:22	Head CT L-Spine (Scout)
01/13/92 11:22	Head CT L-Spine (Std Axial)

Examination History	
Name : Costa, David ID : 123-45-67	
12/21/91 9:18 Head CT L-Spine (Std Axial)	☒
12/21/91 9:18 Head CT L-Spine (Scout)	☐
12/01/91 14:36 Head CT Brain	☒
10/26/91 12:30 Head MR AP/Spine/Lumber/Gad	☒
08/11/91 9:36 Chest CR Chest	☐

A

B

Fig. 2.—Image retrieval in a display station.

A. Patient directory and examination directory shown on text monitor of a 2K display station.

B. If images of patient are not in local storage, the user can retrieve them through the archive center by using the patient examination history directory.

Device failure.—Each of the archive devices, including the archive servers, optical libraries, and data-base servers, is mirrored onto its equivalent equipment. When all these devices are in normal operation, the two archive systems run concurrently but operate independently, each taking care of the archiving of data in the Center for Health Sciences or the Medical Plaza, respectively. If any archive device fails to operate, its mirrored equipment will automatically reconfigure itself instantaneously and carry on the duty of both devices so that no delay in image receiving, image archiving, or image routing occurs.

In the event of failure of an archive server, acquired images in all the acquisition nodes are sent to the second archive server, where they are distributed to destination display stations and archived on optical disks. The failure of an archive server is detected by an acquisition node when the latter attempts to establish a connection to the archive server for transferring images and fails.

If, on the other hand, an optical library fails to work, all the arriving images in its attached archive server are routed to the second archive server and archived to the functioning optical library. The delay in

archiving caused by the routing of images between the two archive servers does not affect any clinical service, since all these images are distributed immediately from the first-arrived archive server through the IPI disks to destination display stations. In addition, a stand-alone optical drive is designated for retrieving an image manually in the event of the failure of an optical library. Moreover, the Sybase SQL utilities running on the two data-base servers have a mirroring effect and the data are duplicated in each of the servers. Therefore, each server functions as a hot backup of the other. The implementation of this commercial data base in redundant machines provides the entire PACS, including the archive subsystem, with a reliable data base for image management.

Network failure.—We use the standard Ethernet networking system to interconnect all the PACS components so that it can be used as a backup of the FDDI and UltraNet networks. Failure of the FDDI or UltraNet network automatically triggers the archive manager to reconfigure the communication networks so that data are transmitted to their destinations over the Ethernet network. The reconfiguration

of the network circuit is done by simply reassigning the destination's network address in the communication software automatically.

Power outage.—Power failures and surges have been a major source of system downtime. To avoid any interruption to the centralized archive operation, we have installed two 50-kVA uninterruptible power supply units (Liebert Corp., Columbus, OH), one each at the Center for Health Sciences and the Medical Plaza, connecting all of the archive devices and acquisition host computers as an emergency power backup. With a 20% full load of these two backup battery systems, our current configuration protects these PACS components from a power outage for up to 2 hr. In the past, the major power outages experienced in both the hospital and the outpatient clinic lasted only 5 min or less. Thus, these two high-capacity UPS units allow future growth of our PACS. This means that more critical PACS components implemented in the future can be attached to these UPS units without overloading the latter.

Clinical Experience and Performance

In order to provide radiologists and referring physicians with the highest priority information about a patient, current images as well as those from the most recent examination are distributed to the destination display stations immediately upon their arrival in the archive servers. Older images for a comparison study can also be retrieved from optical disks upon request and sent to the destination display stations. However, we learned that "service delay" became a primary concern when we moved our PACS from the research and development laboratory to a clinical environment. A $2K \times 2K \times 8\text{-bit}$ (4-megabyte) computed radiographic image, for example, can appear in the display station in less than 2 sec, provided that the image is residing locally on the display station's high-speed parallel-transfer disk (Storage Concept Inc., Irvine, CA). However, if an image of the same size is retrieved from an optical disk through an archive server and sent to the destination display station via the network, a 1–3 min delay in displaying the image is experienced. This is due to the retrieval time required from the optical disk library.

Our current strategy to minimize the time delay is to manage all PACS processes running on the archive servers by prioritizing job control so that urgent requests will be processed immediately. For example, a request from a display station to retrieve an image from an optical disk has the highest priority and is processed immediately. And, upon completion of the retrieval, the image is queued for transmission with a priority higher than the rest of the images that have just arrived from the acquisition nodes and are waiting for transmission. By the same token, an archive process must be compromised if there is any retrieval job executing or pending. The use of job prioritizing and compromise between the PACS processes has resulted in a dramatic improvement in minimizing the delay in servicing radiologists and referring physicians in the clinic [13]. As an example with job prioritizing, a 20-megabyte image file takes 54 sec to be retrieved from an optical library. However, if this image file is retrieved while another large image file is being archived to the same optical library, the retrieval time for the former image will be 96 sec. In other words, the time delay of the retrieval without job prioritizing is 42 sec.

Figure 3 is a histogram of the image data archived in each hour of the day. This histogram shows that over 80% of data

were archived during regular hospital hours (9 A.M. to 5 P.M.). Figure 4 shows the average residence times of individual images in routing to display stations and archiving to optical disks during different hours of the day. The routing residence time was determined by the elapsed time between when an archive server received an image from an acquisition node and when it finished routing the image to a destination display station. Similarly, the archive residence time was determined by the elapsed time between when an archive server received an image from an acquisition node and when it finished archiving the image to an optical disk. Both these two residence times vary significantly with (1) size of the images to be processed, (2) frequency of receiving images from acquisition nodes, (3) frequency of handling retrieve requests from display stations, and (4) size of the retrieved images. During peak hospital hours, for example, at 10 A.M. and 3 P.M., in which the archive servers handled retrieval requests from display stations more frequently, both the archiving and the routing of images required approximately two to three times longer than during early morning and late evening.

Discussion

The digital archive center we established is characterized by its dual configuration, of which two archive systems consisting of identical components, one at the Center for Health Sciences and the other at the Medical Plaza, run concurrently but operate independently. However, the two systems allow the exchange of data between the two sites. In addition, the two systems are mirrored so that each of them serves as a hot backup in the event of failure of the other. With the implemented fault-tolerant mechanism applied in these systems, we experienced a 100% system uptime during the past 6 months. A 100% archive center system uptime means that all acquired images from acquisition devices are stored in the center without a single failure. This performance record provides an uninterrupted operation in image archiving for a

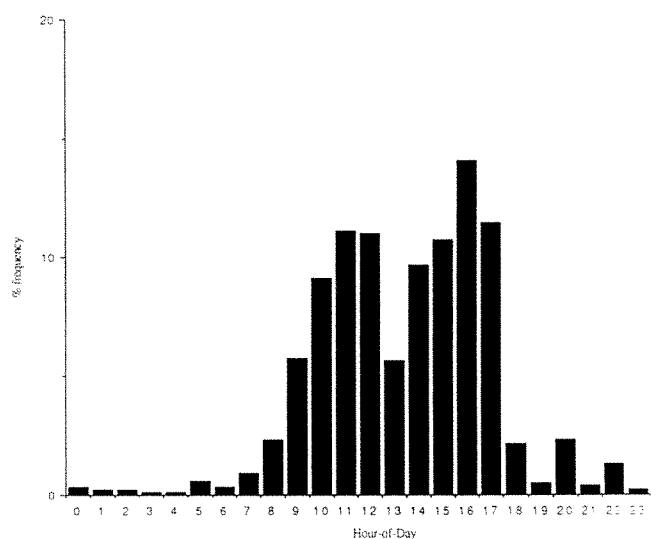


Fig. 3.—Image data archived in each hour of the day. The statistics were based on the 80-gigabyte data collected in September and October 1991.

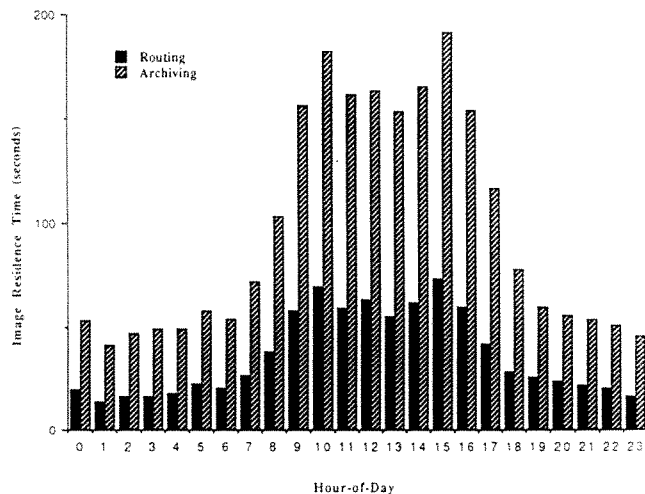


Fig. 4.—24-hr distribution of routing and archiving image residence times in the digital archive center.

department-wide PACS. Currently, each workday the center archives from 1.5 to 2.0 gigabytes of data from three MR units, four CT scanners, three computed radiographic systems, and two laser film digitizers.

Routing of images took two to three times longer during peak hospital hours than at nonpeak times. At present, we have not experienced an impact on clinical usefulness. However, when the system expands in the future, we may have to take steps to minimize this delay. A method of remedy is to change the host computer from the Sun SPARCserver 490 unit to the Sun SPARCserver 690 MP unit. This could potentially double the input/output speed, since image transmission currently is limited by the input/output speed of the computer and not the communication networks.

One dilemma in mass storage is limited storage capacity. For example, the two optical libraries in our archive center provide a total storage capacity of 1.36 terabytes, which can sustain the archive of images from three MR units, four CT scanners, three computed radiographic systems, and two laser film digitizers for 3 years without compression. However, we have three additional film digitizers being implemented that will service the clinic in digitizing selected conventional film-screen radiographic images. These images will be archived to optical disks for long-term storage. On the other hand, more radiologic imaging devices will be installed in the clinic owing to the increasing demand on patient care in our hospitals. All these will result in the creation of critical problems in long-term archiving. To avoid this result, at least to some extent, two potential solutions are being implemented. First, a new 10.2-gigabyte optical disk from Kodak will be used to replace the existing 6.8-gigabyte disk for archiving images. The new and the old disks can coexist in the current system. This new disk will increase by almost 50% the current storage capacity of the libraries. Second, a reversible image compression module is being developed in our laboratory and will be adopted to these archive systems so that image data are compressed before they are archived. Even a 2:1 compression will double the capacity of each of the optical disks. The current reversible compression method allows the compression/decompression to be executed almost in real time. Therefore, no delay in system operation should be experienced.

Optical disks are very durable and are not removed from the optical disk library. It is very unlikely that they can be damaged by the robot arm during the fetch operation because of the built-in protection mechanism. They are not subject to the disk-crash phenomenon experienced often in the magnetic disk environment since the read/write operation is through a laser beam. If a disk is ever physically damaged—for example, if it is cracked from being dropped on a hard floor—the image information in the crack will be destroyed. However, the rest of the disk will be intact, since a duplicate copy of the disk directory is always kept in the data base.

Fault tolerance achieved by using redundant equipment is expensive. The hardware cost for the two archive systems with fault-tolerant design is approximately \$900,000. About one third of this amount is for the purpose of image communication, including from the acquisition devices to the display stations. In addition to the added dollar amount in the purchasing and maintaining of equipment, the increasing complexity of the PACS software also doubles the time and effort spent in software development. Software development takes about 5 man-years. However, hardware redundancy and software complexity not only add reliability to the archive systems but also provide more data paths to our PACS. This results in a dramatic improvement in the performance of the entire PACS, since data are spread over two archive devices and their host computers and the multiple communication networks. Therefore, less competition for computer resources, such as CPU (central processing unit) processing, management of disk storage, allocation of the data bus to the low-speed optical disk drives, and network processing, should be expected. With this hardware redundancy, an average increase of 40% in overall performance of individual image files from residing in the archive servers to arriving in the display stations during hospital hours was measured. In a loaded clinical environment, fast service is as important as reliability in building user confidence. This, in turn, will accelerate system acceptance. Despite its expense, our fault-tolerant mechanism undoubtedly achieves both these goals.

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Book Review

Outline of Medical Imaging, vols. 1 and 2. By Louis Kreel and Anna Thornton. Stoneham, MA: Butterworth-Heinemann, 1302 pp., 1992. \$395

In 1971, a 377-page *Outline of Radiology* was written by Louis Kreel. This was a compact, easy-to-use outline of the state of the art of diagnostic radiology and an excellent review for candidates for board examinations. The current work, *Outline of Medical Imaging*, is the lineal descendant of that book, and it is testimony to the complexity of the increase in knowledge of diagnostic imaging technology and disease pathophysiology that has occurred since that time.

The two volumes of the work are organized by organ system rather than by technology, and the second volume has a small chapter at the end on contrast media and pharmacoradiology. The entire work is quite literally an outline. The book contains nothing that a person can simply sit down and read. The outline format is also cumbersome to use for someone trying to gain information about a general topic because often it is necessary to flip from page to page to see subject headings and subheadings. The strength of the book is that it is a massive compilation of isolated facts about imaging findings in particular diseases. Use of the index rather than the table of contents or subject headings is the most effective way to organize a search for this specific information.

The book has no radiographs or other images. All illustrations are line drawings. This format is frequently ineffective, particularly in the illustration of complex serial cross-sectional anatomy of such areas as the mediastinum. Even in the illustrations of findings on plain radiographs, only so many ways exist in which the many different types of holes in bones, for example, can be depicted in line drawings. The illustrations, like the outline format itself, are not as useful for

teaching purposes as they are for prodding the reader's memory about a specific finding in a specific disease.

To some extent, this book does not reflect the contemporary practice of diagnostic imaging. For example, it has a five-page chapter on interventional radiology, but hypotonic duodenography merits a section of the same length. No illustrations of MR imaging of the knee are included. The book also has some other organizational peculiarities. For example, the spinal cord is discussed in the chapter on osteology rather than in the one on neuroradiology, and subperiosteal resorption is mentioned in the chapter on endocrine imaging rather than in the one on bone radiology. A table of the causes of presacral masses is on page 933, but the references to the table are on pages 639 and 1029.

The intended audience for the work is unclear. The book is too long and unwieldy to serve as a review of material for board examinations. Such works as Ravin and Cooper's *Review of Radiology*, the outline of Duke University's board review course, are more efficient short outlines. Books like *A Short Textbook of Clinical Imaging*, by Sutton and Young, are more readable, well-illustrated one-volume texts for junior residents.

This book is exactly what it purports to be. It may find its niche as an encyclopedic compendium of radiologic facts and diagrams, but at the price of \$395, it is an expensive luxury.

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Perspective

Capital Planning in Radiology

James H. Thrall¹

Radiology is a capital-intensive medical specialty. Hospitals have been severely challenged in the last decade to meet the dual needs for replacement of the conventional installed base of radiographic equipment and the acquisition of equipment for the new digital imaging modalities including CT, MR imaging, and sonography. An increase in the number of procedures performed has further added to capital needs, especially since the growth of imaging services has outpaced the overall growth of health care delivery [1, 2]. From 1985 to 1988, the average annual growth of imaging services to Medicare patients was 18%, compared with an average growth of 12% for all services [2]. High-technology or "advanced" imaging services grew by 32% per year.

The rapid escalation and even skyrocketing capital needs in radiology coupled with changes in reimbursement make it increasingly difficult for hospitals to keep up with radiology's capital needs. Underfunding for replacement of old equipment in order to meet capital needs for new modalities has left an aging capital base in many institutions.

In tertiary care centers, each inpatient admission results in multiple imaging examinations. The accessibility of imaging studies and the efficiency of their application are factors, albeit difficult to measure, that determine length of hospital stay. The efficiency of modern hospitals is directly influenced by the quality and efficiency of radiology services, and institutions will be well served to develop plans for the capitalization of their departments of radiology.

Approach to Developing a Capital Plan

Innumerable variations exist for the specific steps in developing a long-range capital plan. The following is based largely on the process used at the Massachusetts General Hospital (MGH). The overall strategy is to create a dynamic analytic model of capital needs. Historically, many institutions have done capital planning on a year-to-year basis, with line-item approvals for radiologic imaging equipment. The interval from recognition of capital need through technical evaluation, development of bid specifications, equipment acquisition, and, finally, installation is now routinely longer than 1 year for major types of equipment such as angiographic, CT, and MR imaging devices. A prospective capital commitment on a 3- to 5-year time horizon is more suitable to the planning and installation process and also allows the institution to negotiate more effectively with vendors. The prospective approach has been in place at MGH for 5 years. From the standpoint of the hospital, it provides a more predictable financial projection than year-to-year planning, and for the department, it allows far more latitude and flexibility in prioritizing capital acquisitions.

The capital plan should include the development of a comprehensive inventory of current equipment; assessment of the equipment's status from engineering, functional, and safety standpoints; calculation of the replacement value of the installed base in today's dollars; identification of any outlier

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equipment requiring immediate replacement; and then a commitment to a prospective multiyear program for acquisition of capital equipment. Needs associated with increases in study volume and addition of new modalities or services are determined in addition to replacement needs and are coordinated with all other long-range planning for the institution.

Capital Replacement Program

The first step in developing all radiology capital plans at MGH is the creation of a comprehensive equipment inventory data base. Each piece of equipment with a purchase value greater than \$1000 and a useful life of 3 years or more is included in the inventory and given a unique identification number.

The inventory data base is analyzed several ways. First, the entire equipment list is sorted by time of acquisition. This makes it possible to compare the age of equipment in the installed base with American Hospital Association (or other) guidelines for estimated useful lives of depreciable hospital assets [3]. MGH does not use these guidelines as a principal indicator for replacing equipment, but they do provide a useful nominal way of comparing the installed base with a nationally recognized accounting standard.

The inventory is then sorted by replacement cost. This provides a useful segregation of the various devices and modalities for planning purposes (Table 1). Sorting in this way by cost or price makes it possible to determine the priority of items for replacement on a more realistic basis than if everything is lumped together. For example, it is simply impossible to compare the need for an MR imaging unit vs a film processor, but it is realistic to weigh the need for MR vs CT or biplane angiography.

TABLE 1: Cost Categories for Radiology Capital Planning at Massachusetts General Hospital

Cost (\$)	Examples
1,000,000+	CT, MR imaging, biplane angiography, positron emission tomography
500,000–1,000,000	Single-plane angiography, multiheaded single-photon emission computed tomographic gamma cameras, "high-end" digital fluoroscopy, "low-end" CT scanners
100,000–500,000	Most conventional radiographic systems, conventional gamma cameras, high-end sonography, computed radiography, add-on digital fluoroscopy
20,000–100,000	Portable radiographic systems, laser film recorders, daylight processing equipment, mammography systems
20,000–	Power injectors, personal computers, monitoring devices, conventional film processors, multiviewers, crash carts

When the cost or value of the installed base is estimated for capital planning, it is extremely important to use the *replacement value* of the equipment and not the *acquisition value*. Virtually everything in use today in radiology will cost more to replace than it did to purchase originally because of inflation and increased technical complexity. For planning purposes, an estimate of the site preparation and installation costs is also included with the estimate of replacement cost in today's dollars.

The aggregate total replacement value of the installed base, including site preparation costs, provides an extremely useful number for thinking about capital planning. A series of assumptions can be applied to this number to determine what an average or "steady-state" replacement program would require. Steady state implies no new technology and no growth in volume. This is unrealistic over the long run, but the approach is useful if repeated with a "rolling" or reforecast 3- to 5-year horizon. Thus, if a 7-year average replacement cycle is anticipated, the yearly average capital need equals the inventory replacement value divided by 7. If a 10-year average replacement cycle is forecast, the annual capital need is the value of the installed base divided by 10, and so on.

This analysis must be qualified further by observing that such an analysis only applies if the age and condition of the installed base are considered satisfactory. If the capital replacement process has been allowed to fall behind, an additional calculation is necessary to determine how much remedial funding is needed to achieve a more even replacement cycle. The magnitude of the remedial funding problem (if any) is easily highlighted by sorting the replacement cost data against the age data and against the equipment condition data described in the following material.

The question of how to determine the "real" useful life of a piece of equipment vs its "depreciable" life is a difficult one that probably has no single crisp answer. The approach taken at MGH is to combine the results of several separate kinds of assessments in a grading system (Table 2). Each piece of equipment is assessed yearly by the department's engineering group and technical director. Each major piece of equipment is given a score from 1 to 5. The score of 5 is reserved for new or nearly new equipment. A score of 1 indicates marginal equipment ready for replacement. Any piece of equipment failing any category of assessment is taken out of service immediately and is not used until it is repaired, upgraded, or replaced.

The dynamics of equipment review can be quite complex. For example, a reliable piece of equipment from an engineering standpoint may no longer provide the kind of imaging studies required. Specific cases are gamma cameras without tomographic capability, sonographic devices without Doppler or color flow capability, single-plane angiographic rooms for some applications, and CT scanners not suited for dynamic imaging. The rapid technical development in digital and cross-sectional imaging can cause equipment to become outmoded before depreciable or service life comes to an end. In many instances, the equipment is still usable for simpler, less advanced applications if more modern equipment is also available in the institution. For example, a gamma camera without tomographic capability may not be considered useful for

TABLE 2: Equipment Grading System Used by Massachusetts General Hospital

Evaluation Criteria
1. Image quality
2. Technical capability, ability to generate required types of studies
3. Radiation level, radiation safety for patient, radiologist, and technologist
4. Safety, mechanical factors
5. Reliability, mean time between failures
6. Maintenance cost
7. Appearance
8. Ease of operation, human factors
9. Labor intensiveness (intrinsic)
10. Compatibility with radiology/health information systems and picture archiving and communication systems

Note.—The grading system is based on 10 evaluation criteria, each rated on a scale of 1–5: 1 = marginal, 2 = poor, 3 = fair, 4 = good, 5 = excellent. The overall rating or grade is based on the cumulative score: 1 = marginal (10–15), 2 = poor (16–25), 3 = fair (26–35), 4 = good (36–45), 5 = excellent (46–50). Equipment that receives a failing score (less than 1.0) in any category is taken out of service.

thallium-201 myocardial imaging but may still be useful for skeletal scintigraphy or pulmonary ventilation-perfusion scintigraphy.

Some devices are in good condition from an engineering standpoint and make images that are diagnostically useful and meet a program's needs but are not acceptable from a health physics standpoint. The best example is mammography. Many units of equipment for mammography have required replacement to meet current optimal criteria for low radiation dose to the patient. Safety and ethical considerations were the deciding factors.

The pieces of equipment at highest priority for replacement are critical or high-volume devices that are considered marginal from an engineering standpoint and that no longer meet optimal functional or safety criteria. The entire inventory of equipment in the department is rank ordered for replacement priority, and required capital dollars for a 3- to 5-year period are projected.

When this approach was most recently applied at MGH, the department identified 344 items of capital equipment. The replacement value of the installed base, including estimated site preparation, was \$46 million in 1992 retail dollars. For an average replacement cycle of 7 years for the installed base, \$6.6 million per year would be required. With a 10-year cycle, the steady state would require \$4.6 million per year.

Capital Program for Increase in Procedure Volume, New Programs, and New Technology

The next step in the capital planning process after a program for the steady-state replacement process is determined is to forecast capital needs resulting from an increase in the number of procedures, new programs, and the acquisition of new technology. At MGH, the forecast of the increase in procedures is determined by looking at the growth history of the hospital, the projections for growth, and the link between hospital growth rates and demand for imaging services.

Two important patterns emerge. First, growth in demand for imaging services has outpaced growth in inpatient admissions and outpatient visits. The medical "value added" from imaging has steadily increased with the advent of new technologies, including CT, MR imaging, and sonography, and the growth in therapeutic interventions. Thus, any estimate must take into account this disparate or divergent trend between imaging and overall rates of service provision [2].

The second important trend is a disparity in the growth rate assessed when using statistics on the numbers of procedures performed vs relative value units (Table 3). The growth in the relative value of services provided exceeds the percentage of growth measured by the number of studies performed. The reason for this is straightforward. Interventional procedures and cross-sectional imaging studies done with CT and MR imaging are counted as only one procedure in statistics on the number of procedures performed but have a far higher relative value than conventional X-ray-based studies like chest radiography or long-bone series. Therefore, it is reasonable and probably necessary to separately project the growth of big-ticket, high-technology studies.

The same applies to sonography, although the equipment is not as expensive. Sonographic procedures are growing rapidly, are likely to continue to grow rapidly, and have a higher relative value than the plain film studies noted. These trends are also reflected in Medicare cost data, as procedure costs reflect relative value [1, 2]. From 1985 to 1988, physicians' payments for standard imaging increased 11% per year, whereas payments for advanced imaging increased 32% per year and payments for sonography increased 24% per year [2].

Forecasting capital needs for increases in the number of procedures performed is both easier and more difficult than

TABLE 3: Increase in the Numbers of Procedures Performed and Relative Value Units at Massachusetts General Hospital

Procedure/Year	Studies		Relative Value Units	
	No.	% Increase	No.	% Increase
CT				
1988	18,936	NA		
1989	19,641	4		
1990	23,406	19		
1991	29,781	27		
1992 ^a	34,000	14		
MR imaging				
1988	3,562	NA		
1989	5,481	54		
1990	9,181	67		
1991	9,416	3		
1992 ^a	10,200	8		
All procedures				
1989	352,100	NA	2,501,895	NA
1990	374,966	7	3,010,252	20
1991	406,116	8	3,428,624	14
1992 ^a	429,304	6	3,658,767	7

Note.—The number of CT scanners was six for 1988–1989, five for 1990–1991, and four for 1992. The number of MR imagers was one for 1988, 1.5 for 1989, and two for 1990–1992. NA = not applicable. Relative value units are based on the Massachusetts General Hospital system and are not the same as the resource-based relative value system.

^a Projected.

developing a plan for equipment replacement. It is easier from the standpoint that it can be readily tailored to the individual institution and coordinated with other known clinical initiatives and growth projections. It is more difficult from the standpoint that until capacity is made available, it is frequently difficult to project the true demand for a service.

Capital needs for new programs or acquisition of equipment for new imaging modalities follows from overall departmental and institutional planning. The major pitfall here is the use of available funds for new technology while not adequately addressing replacement of the installed base. This almost always works in the short run but creates a major capital funding problem over time.

Also, as soon as incremental equipment is added to the inventory, all long-term replacement assumptions must be recalculated. In institutions that are both experiencing increases in the number of studies performed and acquiring new technology, a steady state is never achieved. This emphasizes the dynamic nature of the planning process and the value of a periodic reforecast vs a fixed horizon.

Efficient Use of Capital Equipment

In many institutions, the single best opportunity in radiology to improve capital asset management is the more productive and efficient use of existing high-cost capital equipment rather than the acquisition of new equipment. The old imaging paradigm of one technologist working in an X-ray room and taking care of one patient at a time has been replicated in many institutions for CT, MR imaging, sonography, nuclear medicine, and angiography.

Hospitals have routinely underestimated the staffing necessary to achieve the best overall return on their imaging investment. In a study of CT at the MGH in 1988, only 6% of scanning costs were for materials. Twenty percent of costs were for direct wages and benefits, assuming a single technologist per CT scanner. The remaining 74% of costs were fixed costs for the equipment itself and institutional indirect and overhead costs. Conservatively, a second technologist on each shift increased the number of examinations by approximately 3.0 per shift. The scanners run 16 hr a day, so the total daily increase from adding a second technologist was six patients per scanner. After additional salary costs and the variable cost per examination (e.g., film, contrast material) were paid, the net return to the institution per scanner per year was \$125,000. Scanners are now routinely staffed with a minimum of two technologists, with support from nurses and escorts.

In 1988, the institution was running six CT scanners and performed about 18,900 examinations. In 1992, the institution has reduced this number to four CT scanners and is projecting a volume of 34,000 scans (Table 3). During peak demand periods, three technologists are assigned to each scanner. Routine hours of operation have been extended to include a 12-hr shift for multiple scanners on both Saturday and Sunday. These days are popular with outpatients. Many find it easier to come on weekends when they do not have to leave work for the examination. It is also easier for relatives who

work weekdays to accompany a parent or other family member. This arrangement may not be possible in every setting but has been useful in the urban Boston setting. A similar phenomenon has occurred with MR imaging.

It is interesting to speculate why hospitals have underestimated the amount of staffing needed to achieve maximum productivity. The intuitive strategy almost invariably used for personnel management is that persons should always be busy and never idle. Clearly, if this strategy is followed, the equipment will be underused during breaks, lunch and dinner hours, and so forth, and while technologists are dealing with non-scanning-related issues such as patients' transportation, computer data entry, filming of studies, and scheduling. For full advantage of expensive technology, some overstaffing is necessary to ensure that the equipment is always being used. To put it rather dramatically, one missed scan per day results in a revenue loss greater than the salary of a technologist. The economic modeling is quite clear. The intuition is not, and it is likely that hospitals will continue to underuse their high-cost high-technology equipment.

Another useful exercise that should be periodically carried out in every institution is to look for marginal unused capacity for different imaging services. This marginal capacity represents an opportunity. For example, if a hospital has purchased a new CT scanner or MR imaging system and the equipment is being used only 50% of the available time, additional revenue through a directed-referral managed-care contract is attractive. Discounts for volume referrals make sense if a particular device is not used at full capacity. However, a headlong rush to accommodate managed-care programs through discounted services can be misleading if critical services are already being used at maximum capacity.

Another major opportunity for hospitals in managing their capital assets is in interventional radiology. These procedures can often be performed in angiography or fluoroscopy rooms, where other techniques such as MR angiography and endoscopy are changing patterns of use.

Interventional radiology suites are rapidly becoming like operating rooms but with sophisticated imaging capability. The capital barriers to performing interventions can be reduced by using existing facilities whenever possible. Lengths of stay are significantly less for interventional procedures than for surgery, and effective programs in this area project a contemporary high-technology image for the host institutions.

Patients and third-party payers alike will increasingly seek out effective interventional radiologic procedures. Institutions that foster this growing trend will be at a competitive advantage and will benefit through new referral patterns and increased revenue.

Impact of Changes in Reimbursement and Capital Payment

The change from fee for service and cost reimbursement to prospective payment has made it difficult or impossible to determine the profitability of individual components of a hospital's operation. All microcosting strategies have shortcomings. The advent of diagnosis-related groups (DRGs) for

payment of Medicare inpatient capital costs will only add to the difficulty. However, the capital needs of hospitals have never been adequately met through depreciation schedules. Invariably, replacement of buildings or equipment is far more expensive than the original acquisition cost and therefore not offset by the amount determined on depreciation schedules. Moreover, the Medicare capital pass-through has always been discounted.

Hospitals must increasingly look beyond the funds specifically generated through depreciation of plant and equipment to generate capital funding. When this view is taken, hospitals will simply become more like other businesses that have not had a separate reimbursement for their capital expenditures. In manufacturing and other industries, the capital expenditure is simply part of the overall business plan. It is driven by programmatic or product line and business development needs. The key to success will be better management of capital assets and more efficient use of capital equipment. With the stronger linkage of patient care productivity to payments for capital equipment vs cost reimbursement, institutions will be penalized for acquiring unnecessary or unproductive equipment.

In the long run, it is quite possible that the capital DRGs and the DRGs for inpatient care will be merged. This should not be looked on with alarm or negatively in and of itself. The overall level of reimbursement is far more important than the continued practice in health care of isolating the capital process from the overall reimbursement and business process. In some sense, this should unshackle the hospital planning process and may be more realistic from a business practice perspective than the old system.

New Capital Needs for the 1990s

The major capital expenditure in the 1990s that hospitals have not faced in the past is the acquisition of picture archiving and communication systems (PACS). The systems are also referred to as image management and communications systems. The success of radiology has overburdened the historical manual-based methods for handling images. The pace of modern hospitals and the need to take care of patients quickly and efficiently has put departments of radiology in a defensive posture. The expense for acquiring PACS for large institutions will be in the multimillions of dollars, more expensive than any single imaging device currently in clinical operation. In smaller institutions, the expense will still be substantial although proportionately less. A reasonable approach to the acquisition of PACS is to build out to a full system through the modular implementation of partial PACS or "mini PACS" that address specific needs such as multimodality viewing of digital images or transmission of images to the intensive care units, emergency department, or operating rooms. Computed radio-

graphic systems will also become more common and are natural candidates to be interfaced with PACS.

Institutions can evaluate their needs for PACS by assessing how well their current film handling and reporting systems are working. For example, if loss or nonavailability of studies is considered a problem, PACS can provide a solution. Radiology departments with several geographically separate locations are also prime candidates for PACS.

Computer-based equipment provides an opportunity to perform dynamic imaging and to extract quantitative physiologic and biochemical information, in addition to anatomic and pathologic information, from images. The increasing computerization of radiology will have a capital implication in the purchase of either the imaging equipment itself or workstations for processing the data. However, in addition to the capital costs, new computer personnel will be necessary to run the equipment and perform the analyses. The traditional radiologic physicist will increasingly become a computer scientist. The traditional radiology film librarian will increasingly become a computer operator.

Conclusions

Radiology is one of the most capital-intensive specialties in medicine. Hospitals have been pressed to maintain an appropriate capital replacement program for conventional radiographic equipment at the same time they have had to spend unprecedented capital dollars to acquire equipment for new digital cross-sectional modalities. The aging base of conventional radiographic equipment is a financial time bomb ticking away in the hospital industry. Historical depreciation schedules grossly underestimate capital requirements for replacement of equipment and do not take into account new technology or increases in the number of studies performed. Therefore, a comprehensive capital plan must include a replacement program based on today's dollars, must take into account the hurdle of deferred purchases, and should address both increases in the number of procedures and changes in practice patterns. Hospital administrators will suffer sticker shock as they see their radiology capital expenditure needs for the 1990s. They must overcome this shock because imaging is increasingly central to patients' treatment. Exploratory surgery is far less desirable than "nondestructive testing" through medical imaging.

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Perspective

Subspecialization and Certification in Radiology

Alexander R. Margulis¹

The trustees of the American Board of Radiology agreed at their January 1992 meeting to seek approval from the American Board of Medical Specialties to issue added certificates of qualification in neuroradiology, pediatric radiology, and vascular and interventional radiology [1]. This decision, coming almost 6 years after the American College of Radiology Council adopted in 1986 a policy statement against further subspecialty certification, reflects a dramatic shift in policy. The change recognizes the fact that radiology has slowly and inexorably transformed itself into a multitude of subspecialties that exist alongside the general practice of radiology [2-5]. This transformation was caused by the veritable explosion of new techniques in medicine, which greatly increased the value of radiologic diagnostic contributions to the clinical management of patients [6]. The fact that turf battles have started in almost every radiologic subspecialty also has emphasized the need for certification.

Radiologists, like all physicians, owe their primary allegiance to their patients' welfare. It is important, therefore, to consider whether subspecialization in radiology is needed, whether subspecialties other than the three designated for certification of qualification will be needed, and whether subspecialization along lines of technology also is needed. Finally, one must ask whether subspecialization, prevalent in academic centers, can be applied to community hospitals and outpatient private practice.

Is radiologic subspecialization needed? The knowledge data base in medicine has expanded so rapidly and massively in the last 20 years that it is virtually impossible for a radiologist or any other physician to keep up with the advances in the whole field and also keep up with the galloping technologic progress. Today, this knowledge gap is even more critical as

radiologists are increasingly expected not only to contribute significantly to making diagnoses but also to help stage diseases, guide biopsies, and even participate in or administer therapy. These added responsibilities, along with new opportunities, are forcing the advent of the subspecialists, of those who know the intricacies of and modern developments in medicine in the given field and can use this expertise to select the appropriate imaging study and interpret the images in a meaningful way to help the clinician in managing the patient. As the new approaches to imaging, particularly the cross-sectional techniques, generally depict lesions and their anatomic relationships more clearly, clinician specialists have become very interested in performing radiologic procedures and interpreting radiologic images in their fields. Their professed reason for doing this is that they can perform these functions better than the general radiologist can. Another argument is that imaging techniques can be learned in a relatively short time, whereas it takes years to learn clinical medicine and much effort to stay current in it. Imaging subspecialists, however, can enhance their superior technical expertise fairly easily by acquiring the clinical qualifications of their specialty through additional training and practice.

Will further radiologic subspecialties be needed? The three subspecialties designated by the American Board of Radiology for approval are obviously only the beginning of recognizing the legitimacy of other subspecialties, such as cardiac, chest, genitourinary, gastrointestinal, and musculoskeletal radiology, and, finally, mammography. To propose all of them for approval initially would probably be unwise, as the medical bureaucracy, as with all bureaucracies, needs time to digest and be comfortable with any changes, no matter how logical and even how de facto established they are. The question of

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the need for totally technology-oriented subspecialties also will undoubtedly arise. Subspecialists in sonography will probably question organ subspecialization first. However, unless organ-oriented subspecialists in radiology adopt sonography, the field will be taken over by other clinicians, as has already occurred with echocardiography, endorectal sonography for examination of the prostate, and even obstetric sonography. Where radiologists subspecialize in these areas of sonography, they have generally had the advantage in keeping them in radiology, and their clinical specialty colleagues happily depend on the subspecialized, highly skilled radiologist. In the long run, CT and MR imaging subspecialists are probably not needed. As the imaging method matures and techniques develop, organ-oriented subspecialists routinely take over the examinations in these cross-sectional techniques.

Radiologic subspecialties are already a reality in large teaching centers. In many of them, radiologic subspecialists have formed teams with their clinical specialty colleagues, which has resulted in joint teaching and research programs. The question arises, however, whether subspecialties can be economically feasible in community hospitals and in the outpatient private practice of radiology.

As diagnostic radiology is a consultative specialty, it must reflect the outside world of the practice of medicine. That world is highly specialized and even subspecialized, and radiology must adapt in order to survive. The existence of radiology is important to medicine and to the patients because it must and can ensure continued efforts in advancing the field of imaging. In the private practice of radiology and in academic centers, all radiologists must also be general radiologists, as that keeps the field together and is the foundation on which the subspecialties are built. In private practice, whether in community hospitals or in outpatient centers and

offices, it would be advantageous for radiologists to practice in larger groups to ensure that besides doing general radiology, members of the group can have a major and a minor subspecialty. The chest radiologist and the cardiac radiologist could form a team that also incorporates the interventional radiologist. The neuroradiologist and the musculoskeletal radiologist could join forces and the gastrointestinal and genitourinary radiologists could work together, help out the chest radiologist, and also do mammography. These are just some of the possibilities, and undoubtedly others will emerge.

Will subspecialty certification eventually lead radiology to become a tower of Babel, where no one understands anyone else? The danger is obvious, and that is where knowledge and some practice of general radiology for every subspecialist can serve as the binding collagenous substance. Subspecialization in radiology must overcome all obstacles if radiology is to survive.

Let us not forget that in this world of seemingly endless litigation, ever stricter licensing boards, hospital credential committees, and state and federal bureaucracies, one may eventually be classified and restricted to a type of practice that is determined by the certificate on the wall.

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Memo to Authors

Impediments to Clarity: An Annotated Glossary of Rhetorical Pratfalls and Pitfalls

Robert N. Berk¹ and Elizabeth Whalen²

Authors of manuscripts written for publication in radiology journals are faced with a daunting challenge [1]. They must present a large amount of information, much of which is complex, in a way that readers with various degrees of expertise will understand quickly and easily. Radiologists, whose time for reading journals is extremely limited, and editors, who must be frugal with expensive journal pages, require articles to be well focused and concise. If authors fail to make their message clear, their efforts are wasted because the importance of their work will be lost somewhere in the huge, ever-rising pile of unread or misunderstood research.

Stanley Siegelman, editor of *Radiology*, aptly compares manuscripts to window panes; the manuscript must be sparkling clean—not opaque with verbal fog [2]. Nearly 150 years ago, Stille had a similar idea [3]: “The simplest form of expression that renders the ideas most visible is undoubtedly the best. The style should have transparent simplicity, such that the reader scarcely feels a barrier between his mind and the author’s.”

Medical writing is replete with opportunities for pitfalls (mistakes that may lead to misunderstandings) and pratfalls (language errors that may cause the reader to chuckle in the middle of a serious article). Anyone who has ever tried to write or has studied any type of writing knows that the number of such linguistic pratfalls and pitfalls seems to be endless. Grammarians and language experts have devised a whole lexicon of seemingly mysterious terms to describe rhetorical transgressions and faux pas. A glossary of some of these terms is presented here. We do not mean to indicate that knowing the definitions has importance in itself; rather, we

believe that having an acquaintance with these linguistic pratfalls and pitfalls of medical writing can help the author in several ways. First, after reading the following definitions and examples, authors may begin to notice these or similar problems in their own work. Second, authors who become familiar with these writing problems will begin to write better as they eliminate them from their writing. Third, when authors receive their edited manuscripts back from the publisher, they may be more likely to understand the reasons behind many of the changes made by the editor.

Except as otherwise indicated, the definitions given are derived from definitions in *Webster’s Ninth New Collegiate Dictionary* [4], and some of the examples cited are culled from manuscripts submitted to the *AJR*.

Abbreviations, Overuse of (see “Jargon”)

Acronyms, Overuse of (see “Jargon”)

Adverbs, Meaningless

Definition.—Words that modify adjectives, verbs, or other adverbs but add nothing to the sense of the sentence.

Notes.—Conciseness is a major goal of any medical writing project, so the writer must strive to delete any word that serves no useful function. Writers may note that “very” is often deleted by medical editors because the adjective it describes carries the connotation of “very” (e.g., “very many” does not say much more than “many”). Williams [5] gives a helpful list of other adverbs that add nothing to the meaning the author is trying to convey: *kind of, really, basically, definitely, practically, actually, virtually, generally*.

Also, the good writer will avoid using adverbs to modify words that, in view of their meanings, cannot be qualified; the

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traditional example is "sort of pregnant." No medical writer would use that phrase, but many will use such phrases as "most unique," "almost perfect," "totally asymptomatic," or "quite fatal." In each case, we can tell that the modifier is unnecessary because something either *is* or *is not* unique, perfect, asymptomatic, or fatal—these adjectives cannot be qualified. (See also "Redundancy.")

Ambiguity

Definition.—A statement or word whose meaning is doubtful to the reader; especially a statement or word that can be interpreted in two or more ways.

Notes.—Goodman and Edwards [6] wrote, "Writers should communicate their ideas clearly without ambiguity. . . . Readers should be able to understand a sentence on first reading." Schwager [7] notes that some terms are especially vulnerable to ambiguity when used in medical text; these include "and/or," "in another vein," "in any case," and "significant." Moreover, the subspecialty may cause certain terms to be ambiguous: In an article about imaging arthritis of the extremities, the authors may want to avoid "on the other hand"; in any article in which contrast material is discussed, the phrase "in contrast" could be ambiguous.

Even a seemingly simple two-word title can be ambiguous. One brochure advertises classes on "Writing Research." Do those classes deal with how to write research papers or with what research has been done recently on the writing process? (It turned out to be the latter, but the brochure might be thrown away before the recipient ever realized that fact.)

Schwager [7] places appropriate emphasis on this aspect of medical writing when she says: "In writing, as in editing, one important goal is to ease the reader's task in comprehending, and, above all, to avoid ambiguity." As she implies, if the author's writing is ambiguous, the editor will try to clarify the ambiguities before publication.

For ambiguity caused by incorrect pronoun usage, see "Antecedent, Unclear." For ambiguity caused by dangling or misplaced modifiers, see "Modifiers, Dangling" and "Modifiers, Misplaced."

Anachronism

Definition.—An error in chronology; a misplacing of people, places, or things in time.

Notes.—If an author talks about a study of MR imaging conducted in the 1950s, he or she has introduced an anachronism into the paper. MR imaging did not exist in that decade—it was probably not yet even a glimmer in a physicist's eye.

Antecedent, Unclear, or Incorrect Pronoun Reference

Definition.—Lack of clarity regarding which word a pronoun refers to (i.e., the pronoun's *antecedent*) [8].

Notes.—Whenever an author uses a pronoun, he or she should be sure that the reader can quickly grasp which noun the pronoun refers to. In the long, sometimes convoluted sentences of medical writing, trying to determine what the author meant by "it" or whom the author meant by "them" can be difficult. For example, in the following sentence "them" could refer to either patients or doctors: "Some doctors have difficulty convincing patients that smoking harms their health; group instruction sessions might help *them*."

Huth [9] provides a good two-sentence example, in which the antecedent of "this" is not clear: "Failure of treatment with penicillin could not have been predicted because of the defective assay method used. Unfortunately, this occurs in many hospitals." To correct the problem here, the writer needs to change "this" in the second sentence to indicate what is meant: "this failure," "this inability to predict," or "this assay method."

Archaism

Definition.—An outdated word or group of words.

Notes.—Especially in a fast-moving field such as radiology, descriptive terms change as technology develops. For example, "plain abdominal radiograph" is now preferred to "scout film"; "roentgenogram" has been replaced by "radiograph"; and, most recently, "computer assisted tomography (CAT)" has been replaced by "computed tomography (CT)." The writer who uses outdated terminology may be misjudged as uninformed by manuscript reviewers or readers.

Circumlocution

Definition.—An idea expressed by an unnecessarily large number of words; evasive language.

Notes.—The longer the sentence is, the more opportunities for grammatical errors. Radiologists usually do not talk in extra long sentences, but they often write them. Goodman and Edwards [6] give a wonderful example of a circumlocution that can be easily reduced to a much better sentence: "Patients were asked at this time to indicate to the nurse whether discomfort had been experienced" probably simply means "The nurse then asked the patients whether they had been uncomfortable." One can understand the first sentence, but the second is five words shorter and much more straightforward. Found in a manuscript submitted to the *AJR*, this following sentence also illustrates circumlocution that characterizes flawed writing: "Our patient was a 37-week white female gestational product delivered by the vaginal route to a G2P1 mother."

Cliché

Definition.—A trite phrase or overly familiar expression.

Notes.—Because medical writing tends to be formal, with a few exceptions, clichés have no place in it. For example, a researcher would be using a cliché if he or she described a patient as being "as pale as a ghost" or "thinner than a rail." Such clichés are not only imprecise (how pale? how thin?), they are also inappropriate for scientific prose.

Colloquialism, Slang

Definition.—Conversation, informal style of expression; local or regional dialect.

Notes.—Natives of the Ozarks may say "he don't" and "we ain't" without getting any negative reaction from the listener. This lack of negative reaction may derive from the informality of speaking versus writing or from the acceptance of these phrases in the region. We all know such blatant slang does not belong in medical writing; other colloquialisms (meaning "with talk"—i.e., the way people, perhaps radiologists, talk informally) are more likely to sneak unrecognized into our writing. The following four examples are commonly seen in manuscripts submitted to the *AJR*: "dirty" used for "poorly defined"; "line" used for "catheter"; "hot light" used for "bright

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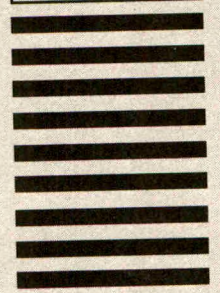
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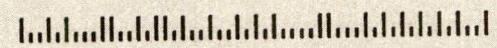
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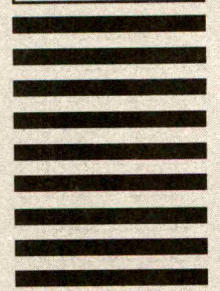
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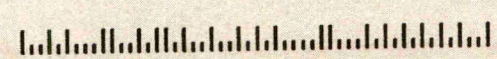
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light"; and "carotids" used for "carotid arteries." To this list we can add some mentioned by Huth [10]: "lab" for "laboratory"; "prepped" for "prepared"; "diabetic leg" for "leg of a diabetic patient"; and "intracathed" for "introduced an intravenous catheter." This may be the way physicians talk to one another—but it is not proper medical writing.

Each researcher must also note that words and acronyms used in his or her laboratory may not be universal. If the writer has any doubt, an outsider should be asked to look at the manuscript to make sure that it does not contain any local laboratory "dialect" that might confuse a reader in another state or country.

Dangling Modifier (see "Modifier, Dangling")

Double Negative

Definition.—Use of two negative expressions within one construction that either makes the actual meaning positive or confuses the reader as to the actual meaning [11].

Notes.—Most frequently at the AJR office, we see the expression "not uncommon." Although most readers will probably realize that this expression does not mean "common" in a medical sense, the two negatives do combine to mean "common" grammatically. Therefore, use of "not rare" is preferable.

Most authors would avoid an obvious double negative such as "we could *not* find *no* tumor." Examples of other, more subtle double negative expressions include the following: "they could *hardly not* order a CT scan," "we had *not scarcely* finished the measurements," and "she did *not* have *but* 1 hr available."

Euphemism

Definition.—An agreeable or inoffensive word that is substituted for one that may suggest something unpleasant.

Notes.—Because the subjects of medical research—illness and death—are not pleasant topics, use of euphemisms is tempting to the medical writer. However, Goodman and Edwards [6] emphasize the necessity for honesty in medical writing, and part of that honesty is the use of the most appropriate word, even if it seems too blunt. For example, scientific style requires that writers discussing the death of a patient use the verb "die" rather than "succumb," "expire," or "pass away." And all good writers will stay away from the atrocious euphemisms exemplified by the well-publicized "negative patient outcome" (meaning "death").

Some British authorities (e.g., O'Connor [12]) will recommend using "kill" instead of "sacrifice," because they consider "sacrifice" a euphemism. However, American animal rights activists have requested the use of "sacrifice" because it connotes that the laboratory animals were not simply killed but "killed for a higher purpose" (i.e., the saving of human health and life).

Gobbledygook

Definition.—Wordy and generally unintelligible language.

Notes.—This type of error is well illustrated by the following sentence: "We advise caution in contemplating orthognathic surgical procedures in patients with active (especially inflammatory) TMJ arthropathy and/or marrow lesions of the mandibular condyle." Most readers will think "Huh?" and try to work out the meaning or they will simply go on to the next

sentence with no understanding of this one.

One way to avoid gobbledygook is to stay away from noun strings and stacked modifiers (see below). Too many prepositional phrases in a sentence also can make a sentence unintelligible: "Two prepositional phrases in a row turn on the warning light, three make a problem and four invite disaster. . . . The *of* strings are worst of all. They seem to reenact a series of hiccups . . . they blur the central action of the sentence—you can't find out what is really going on" [13].

Homophonic Errors

Definition.—Use of an incorrect word because it sounds like the word one wishes to use.

Notes.—Most physicians will not make simple homophonic errors, such as the use of "two" for "too," or vice versa. Probably the most common homophonic error in all writing, including medical writing, is the confusion of "its" and "it's." Remember that "it's" is always a contraction (either for "it is" or "it has") and, as a contraction, has little use in formal medical writing. "Its" is a possessive pronoun (and, like other possessive pronouns such as "his" and "hers," contains no apostrophe); the proper use of "its" can be illustrated by the following sentences: "The new MR imaging unit seemed superior in quality. The clarity of *its* images was much better than that of the images obtained with the older machine."

At the AJR, we often find that authors confuse "ensure," "assure," and "insure." In medical writing, "ensure" is most often the correct choice; it means to "make sure" or "guarantee," as in "the placement of the patient *ensured* optimal visualization of the tumor." "Assure" means to "inform positively" (as in "we assured the patient's family that the patient would not die"), and "insure" ought to be used only when discussing insurance policies that insure against some legal liability (as in "the company insured the doctors against losses from malpractice suits").

Hyperbole

Definition.—Unwarranted exaggeration.

Notes.—When a researcher is excited about the results of a study, he or she occasionally resorts to hyperbole, perhaps calling the results "the most important in medical science in this century." Key words that indicate possible hyperbole—particularly in the Discussion section of an article—are "most" (as in "most interesting," "most surprising," or "most significant" compared with all other studies); "always" (almost always a dangerous word to use in a Discussion); and "never" (as in "this has never happened in the history of medicine").

Imprecision

Definition.—Misuse of words; use of words that deviate from their primary meaning or generally understood connotation.

Notes.—As Goodman and Edwards [6] say, "*Precise* means *accurately expressed*. Something that is precise will be clear and unambiguous, which is what is needed in scientific writing." Precision is almost as important in writing about medical research as it is in the practice of medicine itself. Most books on medical writing discuss use of precise language, and many provide excellent lists of words often used imprecisely [6–10].

Some of the words and phrases we find used imprecisely

in manuscripts submitted to the *AJR* follow: "modality" used when "technique" or "method" is meant, "alternate" confused with "alternative," "quantitate" used for "quantify" or "measure," "comprise" used for "constitute" or "consist," and "symptoms" used alone when "signs and symptoms" is the correct phrase. We also see many references to *patients* being transplanted when actually it is the *organ* that is transplanted; furthermore, physicians diagnose *diseases*, they do not diagnose *patients*. As a final example, in formal writing, "left neck" should be expressed "left side of the neck," and "left heart failure" should be written "left ventricular failure."

Insensitive Language (Dehumanizing, Racist, Sexist Language)

Definition.—Language that is unnecessarily and thoughtlessly offensive to any particular group of people.

Notes.—Physicians have a special obligation to take care that the language they use reflects their view of patients as people. Huth [9] notes several specific ways in which medical writers use language that is "dehumanizing": "cases" used for "patients"; "individual" used for "person"; "male" and "female" used instead of "man" and "woman" (or "boy" and "girl"); and the disease name alone used to name the patient (e.g., "diabetic" for "diabetic patient").

Other types of insensitive language include racist and sexist usages. A scientific article should use the most recent and acceptable names for ethnic groups (e.g., Native Americans, African Americans). Care should also be taken that no assumptions are made about the sex of people in any given profession. One book managed to offend thousands of people by consistently calling all doctors "he," all nurses "she," and all cardiac patients "he." One way to overcome this problem is to use plurals: Instead of "Each radiologist should use the equipment with which *he* is most comfortable," use "Radiologists should use equipment with which *they* are most comfortable."

Jargon, Medicalese, Buzz Words

Definition.—Obscure and pretentious language marked by circumlocutions (see above) and long words; a hybrid, technical language characterized by idioms and used by special groups.

Notes.—One author wrote that, after a child undergoes trauma, he or she might become a "poor historian"; here "historian" is medical jargon used to express a very simple idea: The child may not be able to recall or relate the traumatic incident accurately. In this case, use of jargon makes the sentence silly—it causes the reader to imagine the child later trying unsuccessfully to major in history or to perform a historian's tasks.

We see manuscripts submitted to the *AJR* with such sentences as "Physical examination on admission was remarkable for a cachectic, elderly man." The clearer statement would read, "The patient was an elderly man who appeared to be malnourished and in generally poor health." It is always a good idea to ask another person to read your writing, and particularly to ask the reader to note two signposts of jargon: Was there any sentence that he or she had to read more than once to understand? Was there any word that forced the reader to go to the dictionary (or worse—to guess at its

meaning because the word is not in the dictionary)?

The most inexcusable use of jargon (or medicalese or buzz words [7]) is the attempt to impress the reader with one's extensive vocabulary. "Science can be very complicated, but there is nothing in its definition that implies it must be or [that] requires descriptions of science to be written in any sort of special language that only scientists can understand" [6]. If the reader does not understand the vocabulary, the author's message does not get sent and the author's purpose in writing the piece remains unachieved. No one understands the writing, and no one is impressed.

Another aspect of jargon is the overuse of acronyms and abbreviations. According to Huth [10], "A blight spreading through medical prose is the myriad of abbreviations coined *ad hoc* to substitute for the formal names of diseases, variables, procedures, syndromes, tests, therapies." A wonderful little book, *Medical Abbreviations: 5500 Conveniences at the Expense of Communications and Safety* [14], lists only some of these abbreviations. In general, a writer should use an acronym or abbreviation only if its definition and usage are well established, and he or she should still spell out the acronym or abbreviation the first time it is used. Creating new acronyms for disease names should be reserved for the rare situation in which a very long disease name is used so many times in an article that it contributes significantly to the length of the article. Otherwise, the writer, when in doubt, should spell it out.

Logodaedaly, Neologism

Definition.—Arbitrary or capricious coinage of words [7].

Notes.—English already has an incredible number of words, many of them synonyms; one source [15] says that the 1989 revised *Oxford English Dictionary* has 615,000 entries, but that, if we include technical terms, the number of English words probably totals at least 3,000,000. Before a writer creates a new word, he or she should be very sure that the word is a necessary addition to the language.

Furthermore, a scientific writer has an obligation not to continue the use of an unnecessary new word coined by another author. Goodman and Edwards [6] point out that adding "-able" or "-ible" to existing words has become a popular method of coining new words in medical writing. They make this good point: "Inventions such as *pipettable* and *scanable* might just be acceptable as refreshing neologisms, but the trouble is that these will inevitably reproduce themselves in more complex and ugly forms such as *scanability*." (Or even worse—*scanableness*!)

Malapropism

Definition.—Humorous misapplication of word(s); use of words sounding somewhat like the one intended but ludicrously wrong in the context.

Notes.—Malapropisms usually occur as a result of miscommunication in the writer's office or just a slip of the conscious (not *conscience*) during the process of writing. For example, at the *AJR* office, "metaphysical" was mystically used for "metaphyseal" in one manuscript; in another, "precipitously" (meaning "steeply") was used where "precipitately" (meaning "rashly") belonged. Schwager [7] provides a list of some of her favorite malapropisms from her years of medical editing;

however, this one seems most appropriate for physicians, "The deceased was funeralized on Friday and *interned* at Mount Joseph Cemetery." (One wonders where the deceased did his or her residency.)

Misplaced modifiers (see below) have the same effect as malapropisms—they may make your readers laugh when you really want them to seriously consider your research and its importance.

Medicalese (see "Jargon")

Modifier, Dangling (or Dangling Participle)

Definition.—A modifier (adjective or adverb) placed so that its implied subject differs from the grammatical subject of the clause after it [5] (see also "Modifier, Misplaced").

Notes.—The following precaution may help you recognize a dangling modifier: look for a sentence that starts with a phrase describing something only a human being could do but that does not name any human to do the task described. "In performing this study, 10 rats survived." In this sentence, "performing" grammatically modifies the subject of the sentence ("rats")—but rats can only perform behavior, they cannot perform the study. This problem can be corrected by adding the appropriate subject to the sentence ("In performing this study, we found that 10 rats survived") or by changing the participial phrase to a clause that contains a logical subject ("When this study was completed, 10 rats had survived").

Modifier, Misplaced

Definition.—A word or group of words that modifies one part of a sentence but is placed so that it appears to modify another part [5] (see also "Modifier, Dangling").

Notes.—At best, misplaced modifiers may make a serious sentence comical. In one AJR manuscript, an author wrote "Use of real-time equipment identified a large follicle in eight women who ultimately became pregnant during 77 scanned cycles." This sounds as if babies were conceived during a radiologic procedure! "During 77 scanned cycles" needs to be moved so that it does not appear to modify "became pregnant"—probably moved either before "use" at the beginning of the sentence or after "equipment." Another author warned "Patients with embolic disease should be considered for treatment but approached with caution." In this example, "approached with caution" appears to modify these patients (why are they a threat?). To fix the sentence, a new subject is needed after the word "but": "Patients with embolic disease should be considered for treatment, but *implementation of any treatment in these patients* should be approached with caution."

Modifiers, Stacked

Definition.—Long chains of adjectives and adverbs that give the reader little hint as to which word modifies which [12].

Notes.—Sometimes, in an attempt to shorten manuscripts, authors chain so many adjectives and adverbs together that it is impossible to interpret the meaning of the phrase or the sentence that contains it. As Huth [10] says, "The greater the number of modifiers, the greater is the probability that the readers will not know what modifies what." His example is a classic: "the human spermatozoa-zona-free hamster in vitro penetration test," which may mean "the in vitro test for

penetration of human spermatozoa into hamster eggs that are zona-free." In a veterinarian's office, a pamphlet with this title was found: "Care of the Feline Leukemia Virus Positive Normal Cat" (possible translation, "Care of the Normal Cat Who Has Tested Positive for the Feline Leukemia Virus"). Do we really want to force readers to stop and figure out these complex chains? Not if we expect them to read the rest of the paragraph and the rest of the article.

Neologism (see Logodaedaly)

Nominalizations, Abstract Nouns, Overuse of

Definition.—Overuse of verbs or adjectives that have been turned into nouns [5].

Notes.—In writing as in art, the more abstract the piece, the more likely it is that different interpretations will be made. Watch especially for *unnecessary* nouns ending in "-tion" (the sure sign of a verb made into an abstract noun) that follow a weak or empty verb (such as forms of "to be," "to make," "to do," or "to conduct"). A few examples will clarify how a small change to sentences containing these nominalizations and weak verbs can make the sentence stronger and more concise. (1) "Our *expectation* was to remove the catheter in 4 days" can be changed to "We *expected* to remove the catheter in 4 days." (2) "*Attempts* were made to help the patient breathe" can be changed to "We *tried* to help the patient breathe" ("attempts" is a nominalization of "to attempt"; not all nominalizations end in "-tion"). (3) "The *localization* of the tumor was done by the surgeons" can be "The *surgeons* *localized* the tumor." (4) "The researchers *conducted* the *investigation* of the disease in these patients" can be changed to "The *researchers* *investigated* the disease in these patients."

(And, for those of you who are wondering, "nominalization" is itself a nominalization of the horrendous verb "nominalize"—even linguistic experts are not perfect.)

Nonparallel Structure

Definition.—Lack of parallelism (i.e., failure to arrange equally important ideas in forms that are equal grammatically) [8].

Notes.—A sentence, list, or entire paper can have this problem; parallel structure is worth striving for because it makes the writing much easier for the reader to follow. While lack of parallel structure may jolt or confuse the reader, parallel elements written in parallel grammatical constructions help the reader sail through the text. Schwager [7] gives two excellent examples of sentences that lack parallel structure and therefore tend to send the wrong message. (1) "Healthier living through modification in life style: reduction of weight, salt intake, smoking, stress, anxieties and proper programs of exercise, rest and relaxation." The patient who hates exercise will be happy to interpret this to mean "reduction of . . . proper programs of exercise." Schwager solves the parallelism problem here as follows: "Healthier living through modification in life style: reduction of weight, salt intake, smoking, stress, and anxieties, and *initiation of proper programs of exercise, rest, and relaxation* [italics added]." (2) "Studies with this drug have confirmed its therapeutic value for healing, relief of pain, and epigastric discomfort in certain patients." This statement will lead readers to wonder why one

of the drug's "therapeutic values" is stomach discomfort! Schwager's solution: "Studies with this drug have confirmed its therapeutic value for healing *and for* relief of pain and epigastric discomfort in certain patients [italics added]." Zeiger [8] also provides good examples and exercises in correcting nonparallel structure, including parallelism in sentences, paragraphs, series of figures or tables, subtitles, and comparisons or contrasts.

Noun Cluster, Noun String

Definition.—Addition of one or more nouns to an already existing noun pair [8].

Notes.—Of necessity, medical writers use many noun pairs (e.g., blood flow, radiation therapy). When more nouns are added to modify the noun pair, confusion may result. Zeiger [8] gives two good examples: "filament length variability" is more clear when changed to "variability of filament length"; "air spaces phospholipid pool" can be improved by changing it to either "phospholipid pool *in* the air spaces" or "pool of phospholipids *in* the air spaces."

Oxymoron

Definition.—A combination of contradictory words.

Notes.—Occasionally a writer will fall into the trap of using an adjective that nullifies the meaning of the noun it is supposed to modify. For example, "false facts" is incongruous because a fact by nature is true (use "falsehoods" instead). The "present history" or "future history" of a patient may be interesting, but both combinations are oxymorons—because history, by definition, deals with the past. Schwager [7] shares some of her best examples of oxymorons, including "favorite disease," "guest host," and "conspicuous absence." One oxymoron now very much in vogue in the computer lexicon is the expression "virtual reality."

Passive Voice, Overuse

Definition.—Exclusive or primary use of passive voice (in which the subject receives the action) to avoid responsibility or to try to make the writing look "more scientific" [7].

Notes.—The pendulum keeps swinging in the grammatical pit about whether using passive voice is good writing or bad writing. At one time, the passive voice (in which the subject receives the action, e.g., "the mice were sacrificed") was encouraged in medical or scientific writing, in order to give the appearance of objectivity by avoiding the use of "I" or "we." However, the passive voice has several disadvantages: It usually makes sentences longer, it sometimes distracts from the true subject of the sentence, and it makes the writing less vigorous. For those reasons, writers have been told in recent years that they must *never* use the passive voice. Today, a more balanced view prevails: Authors must make an educated choice whether to use the passive or active voice. *Overuse* of the passive voice, however, is still discouraged. As Schwager says [7]: "It is not 'more scientific' and 'objective' to use the passive voice; it is only more imprecise—and cowardly. However, circumstances sometimes necessitate use of the passive voice to avoid absurdities or convoluted phraseology."

Pleonasm (see "Redundancy")

Pomposity, Prolixity, Verbiage, Verbosity

Definition.—Superfluity of words; wordiness; use of words

that have more letters than equally suitable synonyms.

Notes.—Iles [16] advises writers to try to inform rather than to impress their readers. Deliberately avoiding long words can help avoid unconscious use of jargon. Most books on medical writing contain lists of shorter synonyms for ponderous words or phrases [6–10, 12]; these lists are designed to help the author recognize and correct overly verbose writing.

Precise medical writing often requires use of long, technical terms. But, in manuscripts submitted to the *AJR*, we have noticed several recurring examples of pomposity—unnecessarily long words or phrases—including the following: use of "demonstrate" instead of "show"; "employed" or "utilized" instead of "used"; "prior to" instead of "before"; "following" instead of "after"; "etiology" instead of "cause"; "a relative paucity of" instead of "a few"; "due to the fact that" instead of "due to" or "because of"; and "with the exception of" instead of "except for." The use of these overly long words or phrases may not be intentionally pompous, but the result is the same: the sentence, the paragraph, the article is longer than it needs to be, and the extra words place an unnecessary burden on the reader to ferret out what is important. Those authors who do intentionally use longer words and more words because they are under the mistaken impression that this makes their writing superior should listen to the words of Goodman and Edwards [6]: "If there is a simple maxim for good medical writing, it is that almost always the better word is the shorter word and the better construction has fewer words."

Pronoun, Incorrect Reference (see "Antecedent, Unclear")

Racist Language (see "Insensitive Language")

Redundancy, Pleonasm, Tautology

Definition.—A group of words in which one or more repeat the sense of the other(s).

Notes.—Despite its frequent appearance in medical literature, the phrase "previous history" exemplifies redundancy, because the word "history" already connotes a "previous" time. Other common tautologies in medical manuscripts include "time period," "small *in size*," "oval *in shape*," "to raise up," "close proximity," "total occlusion," "reason *why*," "each and every," and "full and complete" (the italicized words can be deleted with no change in meaning).

Another manifestation of redundancy is the unnecessary adverb, discussed earlier under "Adverbs, Meaningless." Some adjectives (such as "pregnant," "unique," "perfect") denote a condition that either exists or does not exist—qualifiers (i.e., modifying adverbs) are inappropriate or redundant. Specific medical examples from manuscripts submitted to *AJR* include "successfully cured," "completely asymptomatic," "actively invade," and "slightly anechoic"; the underlined adverbs can and should be eliminated—they add nothing but confusion (can one be *unsuccessfully* cured?).

Both types of redundancy are well illustrated by the following sentence: "The weather has been very unseasonable for this time of year." The author should remove "for this time of year" because it repeats the meaning already contained in "unseasonable"; "very" should also be deleted because it adds nothing to the meaning of the sentence (the reader has no idea how "very unseasonable" differs from

"unseasonable").

Sexist Language (see "Insensitive Language")

Slang (see "Colloquialism")

Solecism

Definition.—An ungrammatical combination or use of words (from Greek *soloikos*, meaning speaking incorrectly).

Notes.—Researchers and authors are not expected to be grammarians; however, following the rules of grammar usually makes writing more clear and always makes the editing process quicker and less painful.

One of the most frequent grammatical errors made by medical authors is disagreement between subject and verb; that is, a plural verb used with a singular subject, or a singular subject used with a plural verb. For example, "data" is still considered plural in formal English; so, although you may hear others say "the data is conclusive," the correct written expression is "the data are conclusive." (If, of course, you are talking about only one bit of information, you can write "this datum is conclusive.") Another tricky subject-verb problem is the sentence in which a prepositional phrase (or two) separates the subject from the verb. One sentence read, "CT monitoring of disease activity and response to therapy guide management." The insertion of the phrase "of disease activity and response to therapy" may trick the writer into thinking that a plural verb ("guide") is necessary when actually the subject of the sentence is "monitoring," which must take a singular verb, "guides."

Other grammatical errors include misuse of "who" and "whom," mistakes in punctuation, and disagreement between nouns and their pronouns. Copy editors can correct many of these errors, but authors who want to write more concisely and clearly should make a habit of checking a good grammar book (e.g., Leggett et al. [11]) or a medical usage book (Schwager [7]) when they are unsure of proper usage.

Tautology (see "Redundancy")

Verbiage (see "Pomposity")

Verbosity (see "Pomposity")

Conclusion

As one language expert wrote, "In order to communicate, a linguistic community depends on the shared meanings of words. If there is no shared meaning there is no communication" [17]. For the medical writer, we can add to this message, "If there is no communication, there is no advancement of the science of medicine." Therefore, radiologists, who constitute a linguistic community as well as a scientific community, must write well so that their writings clearly communicate to the readers. Knowing and avoiding the pitfalls and pitfalls is one step toward more lucid writing.

Authors who are interested in improving their style and clarity further should investigate the excellent works cited in the reference list and choose one or two that suit their own tastes. In addition, new books are being written continuously; for example, Oryx Press has recently published books on bias-free language [18] and the best science writing [19].

This glossary has focused on the pitfalls and pitfalls of medical writing, but the qualities that mark good writing must

also be studied. Huth [9] defines in detail five qualities of good scientific prose: fluency, clarity, accuracy, economy, and grace. In a book about basic grammar [20], three criteria are given to define an effective sentence: unity, emphasis, and coherence. Moreover, Zeiger [8] discusses other subjects important to improving writing, including use of topic sentences, key words, transitions, and logical order.

If your research is important, the quality of the writing you do about the research is equally important. And the good news is, as stated by Goodman and Edwards [6]: "The ability to write clearly is a skill, not an art, and it is learned by practice." Therefore, the more you read good writing and practice writing, the more clearly you will be able to write. Then the message you want to send to readers will come across the printed page loud and clear. The authors who improve their writing skills not only achieve publication more quickly and more easily but also attain more effective communication of their ideas, research, and discoveries.

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Letters

Handgun Control: A Public Health Issue

The growing problem of violence in our society is recognized by all, but especially those of us in the health care profession who deal with patients in the emergency department. Firearms, in particular, handguns, are the leading instruments of this violence. In 1991, 60% of all suicides and homicides were committed by persons using firearms. Of these homicides, 75% involved handguns. Although the role of handguns in these fatalities is not in question, an essential issue in research on the prevention of handgun-related mortality is whether limiting the access to handguns would have any effect on these deaths. The debate surrounding this issue has been a political one, with strong arguments on both sides of the question of whether to restrict access to handguns.

Until recently, little conclusive scientific evidence has been available on what effect the restrictive licensing of handguns has on homicide and suicide in America. And the debate has been based almost entirely on emotional and political issues. However, a growing body of scientific medical evidence addresses this area, most recently in a compelling article [1] in the December 1991 issue of *The New England Journal of Medicine*. In this article, Loftin et al. examine the effects of the 1976 law in the District of Columbia that banned the purchase, sale, transfer, and possession of handguns by civilians. All homicides and suicides committed from 1968 to 1987 were classified according to location (within the district of Columbia or in adjacent metropolitan areas, where the law did not apply), mechanism of death (firearms or other means), cause of death (homicide or suicide), and date of occurrence (before or after implementation of the restrictive legislation).

In the District of Columbia, adoption of the handgun licensing law corresponded with a subsequent 25% reduction in homicides by firearms and a 23% reduction in suicides by firearms. No similar reductions occurred during the same time in the number of homicides or suicides committed by other means, and no similar reductions occurred in the adjacent metropolitan areas. Loftin et al. also noted that no compensatory increase in homicides or suicides by other methods occurred; that is, other lethal means were not substituted for the now less available handguns.

What was, before the emergence of this strong scientific evidence, merely a controversial political and social debate has now become a clear-cut medical and public health imperative. As physicians, we should acknowledge that the growing epidemic of injury and death from handguns consumes limited health dollars and medical care resources and wastes human life. The medical profession must take action based on scientific evidence to confront this important

public health issue in order to guide legislation. This is not unlike the similar situation in the case of tobacco use, in which, as scientific evidence grew, the medical community discarded emotional and political issues to become a single voice united for the public good.

Faced with this evidence, we must persuade our professional societies to adopt policies advocating the restriction of private ownership of handguns and automatic rifles and encourage these societies to exert additional pressure to influence state and federal legislation. With this growing scientific evidence, the entire issue of restrictive licensing of handguns has been changed from a political to a public health issue, and we as physicians are morally and ethically obligated to act.

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A System for Full-Motion Real-Time Telesonography

We describe a recent innovation, full-motion real-time telesonography, used in our department to monitor sonograms performed in multiple office sites several miles from the location of the interpreting radiologist.

Our department of sonography currently has Ultramark 4 (Bothell, WA) scanners at two remote sites approximately 15 miles (24 km) from the main department. These remote sites are now linked via the Broadcast Quality Switched Video Service of Bell Atlantic Corporation (Philadelphia, PA). The network consists of a fiber-optic laser system used with the Grass Valley Wavelink Series 3291 (Grass Valley, CA) system for the transmission of National Television Systems Committee (NTSC) video signals. This is an analog system, and there is no digital compression. The fiber video circuits are unidirectional, with one video signal per fiber strand, and conform to the RS-250B

specification of the Electronic Industry Association for short-haul television transmission. The NTSC video output of the Ultramark 4 is attached via a bayonet N-type connector (BNC) to the video circuit, which terminates on a Grass Valley 20 × 10 analog video switch resident in the audio/video operations center of the local telephone company (Chesapeake and Potomac Telephone Co., Washington, DC). The switch allows personnel in the radiology department to select remotely several sonographic feeds from network locations 24 hr a day. The video signal from the switch is delivered to the video monitor at the receive site, where the radiologist is located. A parallel dedicated audio line is used for simultaneous verbal communication with the sonographer, who may wear a telephone headset for hands-free and confidential communication with the radiologist.

The system allows our radiologists to feel confident about interpreting sonograms from remote sites, including routine and emergency obstetric sonograms. Emergency reports can be generated immediately and telephoned to the referring providers without the delay associated with delivery of hard-copy films and videotapes. The network potentially allows remote printing and processing of the hard copies so that film deliveries also can be eliminated. Furthermore, with this fiber-optic-based network, our organization is in a position to take advantage of emerging voice, data, image, and video technologies as they mature.

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An Unusual Cause of Hemoptysis in an IV Drug Abuser

Pulmonary complications associated with IV drug abuse are well known. Thus, hemoptysis in a drug abuser could stem from a number of causes. The following is a report on hemoptysis caused by aspiration of a hypodermic needle in a patient with a history of IV drug abuse. Review of previous chest radiographs showed that the needle had been present for at least 2 years and probably had been overlooked as an artifact.

A 59-year-old man with a history of IV drug abuse (now on methadone maintenance) and chronic obstructive pulmonary disease was admitted to the hospital because of hemoptysis of 3 weeks' duration. The patient reported that before admission, sputum had initially been streaked with blood. Later he had sputum with dime-sized clots of bright red blood two to three times per day. He also complained that he had had increased wheezing and dyspnea on exertion since he had stopped taking several medications. On further questioning, he said that he had noted blood-streaked sputum intermittently over the past 2 years that was not associated with the exacerbation of his bronchitis.

Physical examination showed changes consistent with exacerbation of chronic obstructive pulmonary disease and old healed track marks. Close inspection of a posteroanterior chest radiograph obtained 2 years before admission showed a radiopaque needle in the right main bronchus, which was readily seen in the magnified view (Fig. 1A). It was not well visualized on the accompanying lateral radiograph and most likely had been overlooked as an artifact in the past. On the chest radiograph obtained at admission, the needle was seen in the left upper lobe bronchus and was most clearly visualized on the lateral view (Fig. 1B).

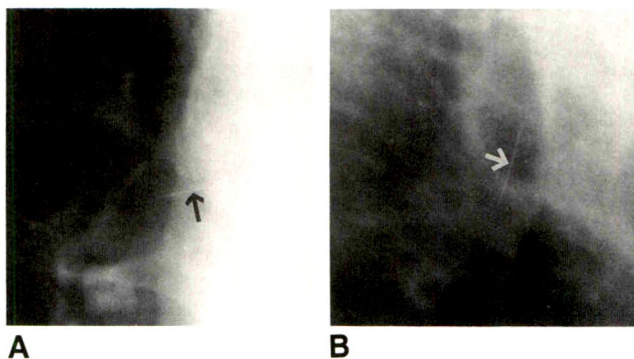


Fig. 1.—Unusual cause of hemoptysis in an IV drug abuser.
A, Magnified view of posteroanterior chest radiograph obtained 2 years before admission shows radiopaque needle (arrow) in right main bronchus.
B, Detailed view of lateral chest radiograph obtained at admission shows needle (arrow) has migrated to left upper lobe bronchus.

Bronchoscopy showed a 25-gauge 5/8-in. (1.6 cm) tuberculin needle in the left upper lobe, with the hub lodged in the lingular orifice. Because of the location of the needle, rigid bronchoscopy was used to remove it [1].

Hemoptysis is a common sign in adults with a foreign body in the airway [2]. In this patient, the hypodermic needle seen on the chest radiographs was most likely the cause of the patient's intermittent hemoptysis over the past 2 years, because these episodes were not associated with exacerbations of his bronchitis. The patient stated that he had often held a syringe in his mouth while he was releasing the tourniquet on his arm after injection of illicit substances, that he had sometimes lapsed into unconsciousness, and that he remembered losing a needle at least once.

A review of information on foreign bodies in the airways in adults indicated that a standard chest radiograph was useful in locating the site of the foreign body in 41 of 57 cases [2]. Metallic and other radiopaque materials are usually easily located, but additional findings such as volume loss, atelectasis, postobstructive infiltrates or air trapping, and mediastinal shift on an expiratory radiograph suggest the diagnosis. Aspiration of needles and pins has been reported in upholsterers, shoe repairmen, seamstresses, and others who use their mouths as receptacles for nails and pins [2, 3]. Use of the mouth as a receptacle for hypodermic needles is probably a common practice among IV drug abusers, and it is interesting that aspiration of needles by this population has not been reported before [4].

I suggest that a high index of suspicion and close inspection of possible film artifacts is warranted in a patient with hemoptysis. If a film artifact is suspected, comparison with previous chest radiographs may be helpful. This may lead to a diagnosis of needle aspiration, particularly in a patient with a history of IV drug abuse.

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Glass Foreign Body in the Breast Simulating a Hyperdense Nodule on Mammography

Foreign bodies in the breast are relatively rare and are mentioned only briefly in standard mammography texts. Metallic objects are discovered occasionally during routine mammography, but a review of the English literature of the past 25 years did not show any reports of glass foreign bodies in the breast. Kopans [1] mentions the possibility of such an occurrence but does not illustrate a case.

Screening mammograms of a 61-year-old woman showed a hyperdense ovoid opacity 1.0×0.5 cm in the inferomedial quadrant of the right breast (Fig. 1A). No other significant findings were noted in either breast. No previous mammograms were available for comparison, and no palpable abnormalities in the breast were present. Coned compression spot magnification mammograms showed that the margins of the nodule were slightly indistinct. The abnormality could not be detected on sonograms. The nodule was classified as indeterminate, and because of the patient's age and a history of a bowel neoplasm, needle localization biopsy was recommended.

The pathologic specimen consisted of a fibrofatty fragment of breast tissue containing the localizing wire and, adjacent to the wire, a clear, irregularly shaped fragment of glass $1.2 \times 0.7 \times 0.7$ cm (Fig. 1B). No masses or cysts were found. Histologic examination showed a glass foreign body surrounded by mild chronic inflammation and fibrosis in otherwise normal breast tissue.

This unusual and surprising result was discussed with the patient. She had never had any signs or symptoms related to the foreign body, and she did not know how the fragment of glass might have entered her breast or how long it had been there. She had been ejected through the windshield of a motor vehicle in a collision when she was 2 years old. We assume that the glass entered her chest at that time.

Glass fragments in the spinal region, visualized on radiographs, were reported by Jennett and Watson [2], who thought that a variable amount of lead oxide accounted for the opacity of glass on radiographs. Roberts [3] has stated that mass and density alone may be enough for visualization of glass on radiographs if the glass does not contain lead. Ordinarily, the patient has a history of penetrating trauma caused by a glass object, and the history in combination with a characteristic outline in the soft tissue make detection of a glass foreign body relatively easy.

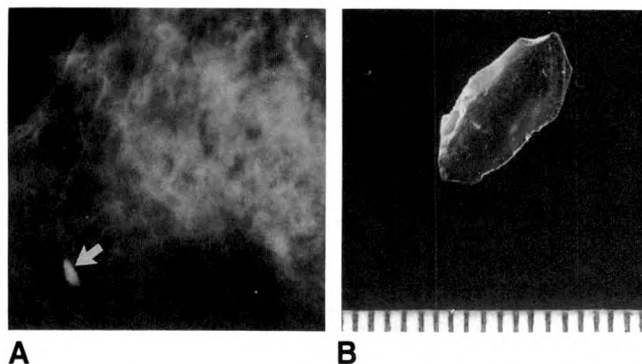


Fig. 1.—Glass foreign body in the breast.
A, Craniocaudal mammogram of right breast shows an ovoid hyperdense nodule (arrow) with slightly irregular margins in deep medial location.
B, Photograph shows glass fragment has variable thickness and slightly irregular margins. (Scale = millimeters)

In our case, a follow-up mammogram obtained 6 months after the screening mammograms could have confirmed stability of the lesion. However, as we had no previous mammograms for comparison and as the patient was 61 years old and had recently had a bowel neoplasm, needle localization biopsy was the reasonable diagnostic option for a hyperdense noncalcified indeterminate nodule in the breast.

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Unfavorable Outcome of Recent Breast Cancer Screening Trials: Why?

The Health Insurance Plan of Greater New York breast screening study and the Swedish two-county trial showed that 30–40% reductions in the number of deaths caused by breast cancer are possible when screening mammography is used to detect the disease. Five more recent trials, including the one in Malmö [1], have not shown comparable benefits. In the Malmö trial, for women less than 55 years old, deaths due to breast cancer were 29% higher in women who had screening mammography than in the control group who did not. This is puzzling because the technology has improved, the dose of radiation is vanishingly small, image quality is excellent, and the number of women screened is large. The question arises: Have any changes occurred in the practice of mammography that might account for the differences in benefits achieved in different trials?

In the *Technologist Guide to Mammography* [2], Egan reveals that mammographic compression was originally an elective procedure and that only a small compressive force was used: "The cone rested on the superior aspect of the breast or a balloon was used." Egan explicitly states that the test should not be painful, although the reason for this restriction is not spelled out. Good mammographic technique now generally requires compression for every patient, including those with carcinoma, and the compression frequently is increased to the limits of the patient's tolerance. In short, the mammographic examination differs from what it was in the 1960s when the Health Insurance Plan study was done. In the United Kingdom, a new compression force limit of 200 N (equivalent to 20 kg) has been introduced [3]. The reasons for the choice of this value have not been published.

We have examined the literature for clues as to how Egan [2] arrived at his recommendations. Many authors have cautioned against careless palpation of breast carcinoma because the procedure might disseminate the disease. A substantial body of evidence has indicated that digital compression of animal tumors increases the number of circulating cancer cells and cancer cell emboli. In a recent article [4], Liotta described how the French physician Recamier advocated compression as a treatment for breast cancer and commented that it was thought that such treatment would inhibit the spread of the disease. However, Liotta goes on to say, "We now know that the treatment would have ensured dissemination of the cancer cells into the circulation." He is pleased to recount that this treatment never became popular. Inasmuch as breast screening is designed to detect the disease before metastases have occurred, it is vital that the test itself does not cause dissemination.

We have examined the United Kingdom guidelines on quality assurance for mammography, and we have found that the emphasis is on achieving adequate compression to ensure high-quality images. In the Malmö study, the general principle was to compress the breast as much as possible without causing the patient substantial pain (I. Andersson, personal communication). No data on the amount of the compressive force used are available.

How might compression pose a risk? The periphery of malignant tumors frequently is composed of a chaotic mass of friable and easily broken vessels. This condition can be visualized with color flow Doppler imaging. Roberts [5] also stresses that whereas considerable force is required to fragment normal tissue, even minor trauma can cause fragmentation of malignant tissue.

In our laboratory, elastic phantoms containing model lesions have been constructed and used to show how compression can fracture the lesion or tear the tissue around the lesion. In practice, the site of damage depends on the choice of compressibility coefficients. Calculations have been done to estimate the magnitude of the strains compression of a lesion can cause.

All the breast screening trials appear to show, at best, small reductions in mortality in the younger women who are screened. The elastic properties of the breasts of young women (dense) differ from those of the breasts of older women (fatty). Even if the compressive forces were the same for all women screened, regardless of age, the applied pressure would vary, depending on the area of contact between plates and tissue.

The size of the, presently hypothetical, risk from excessive compression of neoplastic tumors can be determined in principle by measuring the number of circulating cancer cells before and after mammographic compression of a tumor-bearing breast. Also, it should be possible to obtain mammograms both with and without compression in a patient with breast carcinoma. The differences in geometry of the images could be used to calculate the amount of strain caused by compression. Another technique that might be useful is introduction of dyes into the center of animal tumors. Postmortem examination of compressed tissues should reveal sites of tissue tearing. Studies are needed to see if compression has any relevance to the risks and benefits of screening. It does seem anomalous that the earliest trial (the Health Insurance Plan trial), the one in which the most primitive equipment was used, showed one of the most significant reductions in mortality from breast cancer.

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"Ductogram" Associated with Extravasation of Silicone from a Breast Implant

Since silicone breast prostheses have been marketed, approximately 2 million women have had these augmentation devices im-

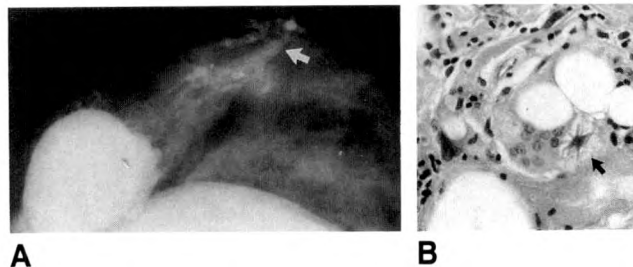


Fig. 1.—Extravasation of silicone from a breast implant in a 37-year-old woman.

A, Craniocaudal mammogram of left breast shows saccules at lateral aspect of implant. Diffuse increased density is associated with extravasation of silicone, and visualization of several ducts (arrow) in retroareolar region is also due to extravasation of silicone.

B, Photomicrograph of biopsy specimen shows foreign body reaction to silicone. Breast parenchyma has round cavities surrounded by lymphocytes and numerous multinucleated giant cells that contain silicone (arrow) in their cytoplasm.

planted, mainly for cosmetic reasons. Recently, the Food and Drug Administration requested a moratorium on the insertion of silicone implants because of concerns about their safety, such as leakage of silicone and possible resultant inflammatory reaction [1]. Increased risk of cancer, though a concern, has not been documented. Other problems with these implants include pain, infection, capsular contractions, and difficulty in mammographic detection of malignant tumors. An unusual complication is extravasation of silicone, with resultant leakage into ducts, causing the appearance of a "ductogram" [2]. We describe a patient who had silicone implants and whose mammograms had this appearance.

A 37-year-old woman with silicone breast implants had pain of recent onset in the left breast and a mass at the upper outer aspect. A mammogram showed rupture of the implant and a collection of silicone that corresponded to the palpable mass. Leakage of silicone extended into the axilla. Increased density of ducts due to leakage of silicone into these structures was noted (Fig. 1A). At surgery, silicone collections that had permeated the breast parenchyma were found, and it was apparent that both implants had ruptured. Silicone was found throughout both breasts. Biopsy specimens showed fibrosis, fat necrosis, and granulomatous and sclerosing inflammation throughout the breast parenchyma and within ducts, associated with the effects of silicone (Fig. 1B).

Difficulties related to the presence of silicone implants have been reported, but perhaps the most serious is that implants obscure breast parenchyma on mammography, leading to difficulty in diagnosing early breast cancer [3]. Leakage of silicone into ducts might prevent early detection of microcalcifications in these structures.

Biopsies in patients with ruptured implants can show foreign body reactions and scarring due to extravasated silicone. The hard breast masses, in this case, had numerous round cavities, which formerly contained silicone, surrounded by an infiltrate of lymphocytes, histiocytes, and multinucleated giant cells. Although silicone is inert, the oils and fatty acids added to silicone breast implants tend to induce scarring [4]. The scarring decreases migration of silicone in the event of rupture. In this case, the breast parenchyma showed fibrous, granulomatous inflammation and fat necrosis.

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Jejunogastric Intussusception: Diagnosis Based on Sonographic Findings

A 51-year-old man was admitted because of central chest pain. On the basis of ECG and laboratory criteria, inferior myocardial infarction was diagnosed. The patient had a history of recurrent duodenal ulcers and had had a Billroth II gastrojejunostomy 15 years before. Two days after admission, he had acute onset of severe epigastric pain without hematemesis or melena. The epigastrium was tender to palpation, without guarding. Laboratory tests showed no cause for these symptoms. Abdominal sonography showed the fluid-filled gastric remnant containing an echogenic mass 10 cm in diameter that had a "target" appearance (concentric echogenic rings) in transverse section (Fig. 1). No peristalsis was evident. The diagnosis was jejunogastric intussusception, which was confirmed with endoscopy. Laparotomy showed intussusception of 60 cm of jejunum into the stomach. Manual reduction and jejunal fixation to the transverse colon were performed; bowel resection was not necessary.

Jejunogastric intussusception is a recognized complication of gastrojejunostomy, particularly the Billroth II procedure [1]. The prevalence is reported to be 1.5 per 1000 [2]. Chronic intermittent intussusceptions with spontaneous reduction occur far more frequently than does acute symptomatic intussusception, which is potentially fatal [3]. The diagnosis of jejunogastric intussusception is usually established on the basis of radiologic findings. Sonography has been a standard technique for diagnosis of intussusception in children. Reports of intussusception in adults generally have been published more recently [4]. The typical appearance consists of concentric echogenic rings (target sign), independent peristalsis of both parts on real-time scanning, and demonstration of the underlying abnormality (e.g., polyp) [4]. Treatment aims at urgent reduction, and surgery is usually required in the case of jejunogastric intussuscep-

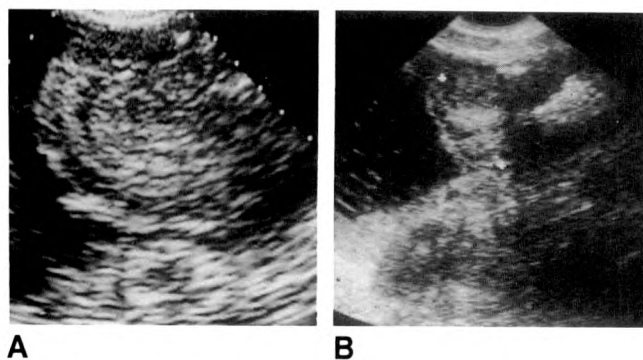


Fig. 1.—Jejunogastric intussusception in an adult.
A, Abdominal sonogram shows fluid-filled gastric remnant with echogenic 7 × 10 cm mass with a "target" sign.
B, Longitudinal sonogram shows echogenic mass within stomach; no peristalsis is evident.

tion. Depending on the underlying pathologic and surgical findings, simple reduction, bowel resection, or surgical correction may be indicated.

In establishing the diagnosis of intussusception in an adult, sonography is of special importance because of its rapid bedside availability and lack of invasiveness. The diagnosis can readily be made on the basis of the typical appearance, enabling rapid institution of appropriate treatment.

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Persistent Pseudotumor of the Bowel on Sonography Caused by Stool in the Colon

Pseudotumors of the bowel are described as predominantly small and round, whereas large masses, particularly if irregular in outline, are said to represent solid tumors of the cul-de-sac or rectosigmoid colon [1].

A 31-year-old woman was referred for sonography because of recurrent pelvic pain. Transabdominal (Fig. 1A) and transvaginal (Fig. 1B) sonograms showed a complex mass 7 cm in diameter that was solid, irregular in contour, and heterogeneous in echogenicity. The

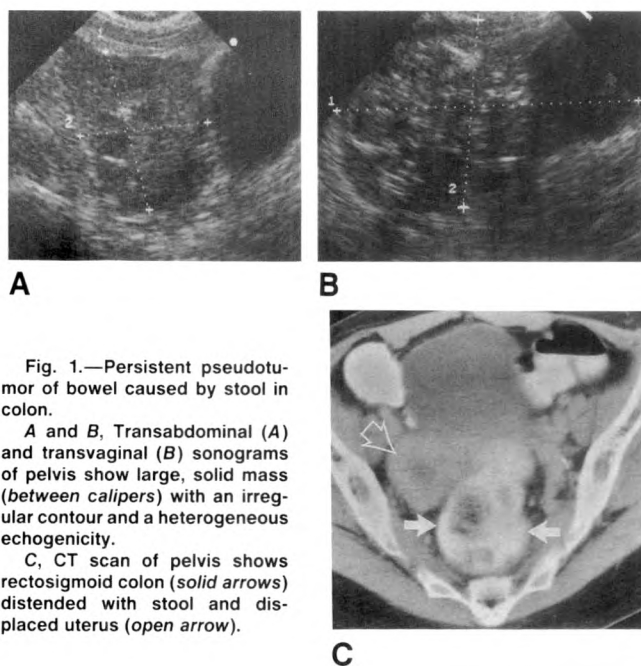


Fig. 1.—Persistent pseudotumor of bowel caused by stool in colon.

A and B, Transabdominal (A) and transvaginal (B) sonograms of pelvis show large, solid mass (between calipers) with an irregular contour and a heterogeneous echogenicity.

C, CT scan of pelvis shows rectosigmoid colon (solid arrows) distended with stool and displaced uterus (open arrow).

mass, which could not be distinguished as an entity separate from the ovary, was posterior to the uterus, displacing the uterus to the right. No peristalsis was detected within the mass, and the configuration of the mass did not change over time. The patient said she had normal bowel movements. Differential diagnosis included ovarian neoplasm, a solid tumor of the cul-de-sac, and possible pedunculated leiomyoma of the uterus. The diagnosis of pseudotumor was considered but thought highly unlikely because of the size and irregular contour of the mass, the complete lack of peristalsis, and the lack of change in appearance over time.

The patient had repeat transvaginal sonography the next morning after a bowel movement. The mass was unchanged. CT scans with oral, rectal, and IV contrast material showed a significant amount of stool distending the rectosigmoid colon and displacement of the uterus to the right, but no mass (Fig. 1C). The patient evacuated the colon, and transvaginal and transabdominal sonograms were obtained, which again showed the pelvic mass. Although the mass did not appear to change considerably in size or configuration, the CT results suggested a pseudotumor. Transvaginal sonography combined with a water enema was then performed. The water took several seconds to enter the mass, but soon showed that the mass was stool.

The size of this mass, its irregular contour, and the complete lack of change in size or configuration during the course of several studies led us to think that the mass was a neoplasm. According to current literature [2], this mass fit in the category of solid tumor of the cul-de-sac or rectosigmoid colon. Its persistence led to several radiologic studies. The most reliable for diagnosis was a combination of transvaginal sonography and water enema.

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Osteoclast-Type Giant-Cell Tumor of the Pancreas

A 41-year-old woman was hospitalized for evaluation of an epigastric mass and pain in the left upper quadrant. Physical examination showed a smooth palpable mass in the epigastrium and mild hepatosplenomegaly. Sonography showed a large mass in the pancreatic body with mixed echogenicity (Fig. 1A), marked splenomegaly, and portal and splenic thrombosis. CT showed a bulky mass in the body and tail of the pancreas, which had irregular areas of enhancement after bolus administration of contrast material (Fig. 1B), portal and splenic vein thrombosis, and marked splenomegaly. Retroperitoneal extension and encasement of mesenteric vessels were not detected. At surgery, the mass could not be resected because of involvement of vascular structures. Intraoperative fine-needle aspiration was performed, and histologic examination showed osteoclast-type giant-cell carcinoma of the pancreas.

Osteoclast-type giant-cell carcinoma is a rare pancreatic neoplasm histologically indistinguishable from skeletal giant-cell tumor [1]. It must be distinguished from the more usual giant-cell neoplasms of the pancreas that contain atypical pleomorphic giant cells [1-3]. Microscopic examination shows numerous multinucleated osteoclast-like giant cells within a stroma of oval, polygonal, or plump spindle-shaped mononuclear cells with various degrees of pleomorphism [2]. CT scans obtained in three cases of pancreatic osteoclast-type giant-

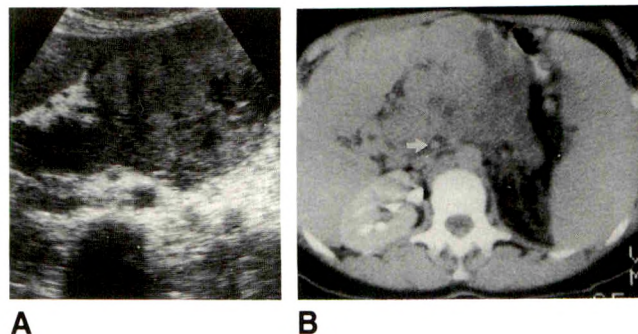


Fig. 1.—Osteoclast-type giant-cell tumor of the pancreas.

A, Transverse sonogram shows large epigastric mass with mixed echogenicity anterior to aorta and superior mesenteric artery.

B, Contrast-enhanced CT scan at level of porta hepatis shows large pancreatic mass with several areas of low attenuation. Note superior mesenteric artery (arrow) surrounded by fat, without evidence of tumoral involvement.

cell tumor have revealed pancreatic masses with areas of low attenuation consistent with necrosis [1, 3]. In one case [1], mesenteric vessels were encased by tumor, which showed retropancreatic extension toward the aorta, but no metastases were detected.

In our case, the tumor was a large mass in the body and tail of the pancreas. The tumor showed irregular enhancement after administration of contrast material and had low-density areas corresponding to hemorrhagic necrosis. Portal and splenic vein thrombosis resulting in severe portal hypertension is a finding previously not reported for this tumor. In contradistinction to this marked portal infiltration, retropancreatic extension toward the aorta and thickening of the superior mesenteric artery were not detected, and the surrounding fat was preserved. In conclusion, the findings in our case enlarge the spectrum of radiologic findings in this tumor, but the usefulness of CT and sonography in the preoperative diagnosis of this entity is uncertain.

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Tiny Echogenic Foci in the Liver

In the January 1992 issue of the *AJR*, Bray et al. [1] describe multiple tiny echogenic foci in the liver and kidneys of a patient with AIDS. Their illustration in Figure 1 in the paper brought to mind a similar appearance that my colleagues and I [2] described in patients with miliary tuberculosis of the liver. Virtually identical echogenic nodules were present. As our patients were infected with *Mycobacterium tuberculosis* and their patient was infected with *Mycobacterium avium-intracellulare*, the similarity is not surprising. As miliary tuber-

culosis can involve a compromised host, the differential diagnosis of such an echo pattern could include miliary tuberculosis.

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Testicular Microlithiasis

We read with interest "Testicular Microlithiasis: Sonographic and Clinical Features," by Janzen et al. [1] in the May 1992 issue of the *AJR*. We have studied two patients in the past year who have had testicular microlithiasis. Both had a unilateral seminoma (Fig. 1A) with no evidence of calcification within the lesion. Both patients were otherwise healthy young men, 27 and 35 years old, respectively. Neither had a history of abnormal testicular descent, chromosomal abnormality, or any known fertility problem. One had classic minute speckled calcifications in the epididymis (Fig. 1B). Epididymal involvement has not been previously reported.

We agree with Janzen et al. that testicular microlithiasis is uncommon and apparently asymptomatic, and that the occurrence of a malignant tumor may be coincidental. However, the occurrence of neoplasms in our two patients suggests that yearly follow-up sonography in patients with testicular microlithiasis is justifiable.

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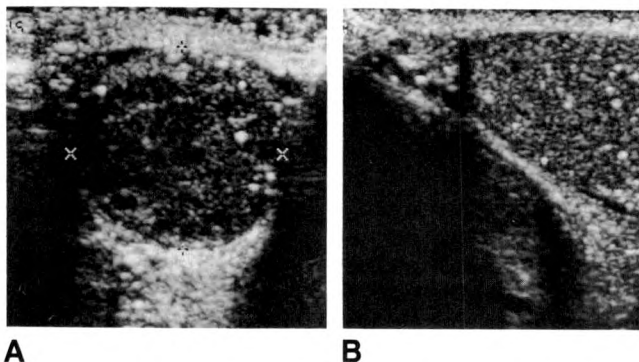


Fig. 1.—Testicular microlithiasis in a 35-year-old man.
A, Right transverse sonogram shows a large intratesticular mass compressing normal testicular parenchyma involved with microlithiasis.
B, Longitudinal sonogram of left testicle shows typical microlithiasis, with speckled calcification in caput of epididymis also.

Reply

My colleagues and I thank Kutcher et al. for their interest in our article [1]. We agree that testicular neoplasm and testicular microlithiasis can coexist. Indeed, we described three such cases in our article, and we found that the microlithiasis did not interfere with sonographic visualization of the tumors. However, only a few cases of testicular microlithiasis have been described in the literature to date, and we think that no conclusions can be made about whether patients with this disorder are at increased risk for testicular neoplasm. We concluded that clinical or sonographic surveillance may be prudent, and we think that the suggestion of Kutcher et al. regarding annual sonography is reasonable. We wish to emphasize our belief that the typical sonographic appearance of testicular microlithiasis is not by itself a justification for orchiectomy or testicular biopsy.

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Abdominal Aortic Aneurysm

With the liberal use of diagnostic techniques such as sonography and CT, physicians are increasingly confronted with patients who have asymptomatic abdominal aortic aneurysm; therefore, knowledge of current treatment strategy is mandatory. The true mortality rate from ruptured abdominal aortic aneurysm is high (more than 80%) [1]. The operative mortality is between 29 and 52% [2]. As the rate for elective repair is now less than 5% in most centers, the chances for survival of patients with abdominal aortic aneurysm can be improved by early detection and elective repair of suitable cases. The only reliable predictor of rupture is the diameter of the aneurysm, although even small ones may rupture. Apart from the diameter, the age and general health of the patient are important when elective surgery is considered.

It is generally accepted that every asymptomatic abdominal aortic aneurysm needs, at the least, serial follow-up with sonography every 6 months. Elective repair is usually considered when the diameter of the aneurysm exceeds 50 mm, although some [3] advocate surgery for all patients who have asymptomatic abdominal aortic aneurysm. After treatment, expected long-term survival is comparable to that of matched population control subjects [4].

To study the diameter of abdominal aortic aneurysms at the time of rupture or shortly before (within the preceding year), we reviewed the records of all 91 patients who had been admitted to our hospital with rupture of an abdominal aortic aneurysm between 1983 and 1990. In 43 cases (38 men, five women) the maximum anteroposterior diameter was measured by using either sonograms or CT scans. In 25 cases, this was done on admission and in 17 cases within the preceding year (mean, 4.1 months). The latter 17 all had vital contraindications for planned surgery. The mean diameter was 69 mm (range, 40-90 mm). We found no important differences between findings in men and women. In 35 cases (81%), the diameter exceeded 60 mm, and in 41 cases (95%) it exceeded 50 mm. The diameter of almost all the abdominal aortic aneurysms that ruptured

exceeded 50 mm, which underlines the importance of this critical size.

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Primary Neuroblastoma of a Vertebra: An Unusual Location for a Variant of Primitive Neuroectodermal Tumor of Bone

Primary primitive neuroectodermal tumor (PNET) of bone is a rare neoplasm that occurs in children and young adults. Its true prevalence is unknown because of the infrequency of reported cases and the current controversy in distinguishing it from Ewing's sarcoma [1]. We report a particularly unusual case of a PNET of bone.

Excruciating back pain and leg weakness developed abruptly in a previously healthy 31-year-old man. On arrival at the hospital, he had a rapidly progressive paraparesis and a T10 sensory level deficit. Because of his rapid neurologic deterioration, emergent CT myelography was performed. An expansive soft-tissue mass destroying the anterior and posterior elements of T10 was seen. The mass also caused encasement of the spinal cord and extended into the posterior mediastinum, destroying the heads of both 10th ribs (Fig. 1A). These findings were compatible with a nonspecific aggressive metastatic neoplasm or a primary skeletal sarcoma. An extensive workup did

not indicate additional sites of disease. A lateral transthoracic approach to the spine was used for resection and stabilization. Because of the mediastinal extension of the tumor, only a subtotal resection was possible. The results of histopathologic (Fig. 1B) and immunohistochemical studies of a surgical specimen were consistent with a PNET of bone with neuroblastic differentiation.

Until recently it has been maintained that osseous involvement with classical neuroblastoma is always a manifestation of metastatic disease from a visceral primary tumor [2-4]. Several recent reports [3-5] have described cases of primary malignant neoplasms of peripheral soft tissue and bone that either strongly resemble or are indistinguishable from classical neuroblastoma. These small, round-cell neoplasms of bone have recently been recognized by some investigators as a distinct category of PNET occurring in the skeleton [3, 5]. The three most common sites of involvement of PNET of bone are the extremities, pelvis, and scapula. The prognosis is uniformly poor; the tendency is early development of metastases and incomplete response to therapy.

Despite the lack of specific radiologic findings, this case is particularly noteworthy because of the unusual site of origin of this type of neoplasm and its differentiation into classical neuroblastoma. To our knowledge, a primary neuroblastoma (or primitive neuroectodermal tumor) of the vertebra has not been previously reported.

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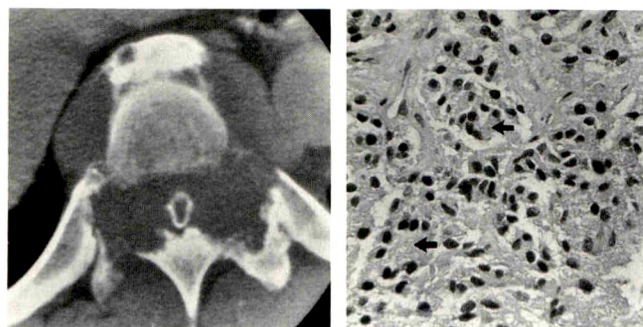


Fig. 1.—Primitive neuroectodermal tumor of bone.
A, Axial CT myelogram at level of T10 shows a destructive soft-tissue mass involving anterior and posterior vertebral elements and adjacent ribs. Note circumferential thecal encasement with severe compression of spinal cord.
B, Photomicrograph shows a mildly pleomorphic small-cell neoplasm surrounded by a thick fibrovascular stroma. A few irregular Homer-Wright-type rosettes are present (arrows). (H and E, original magnification $\times 485$)

Recurrent Adult-Type Pharyngeal Rhabdomyoma: MR Appearance

A 64-year-old man had had an intraoral mass sensation for 6 months. He had had a left-sided pharyngeal rhabdomyoma removed 25 years earlier. Physical examination showed a large, soft, nonfluctuant left-sided oronasopharyngeal mass with involvement of the soft palate and encroachment on the airway. No involvement of the larynx and hypopharynx was noted. MR imaging showed a large, lobulated, well-defined, homogeneous mass lesion involving the left lateral wall of the nasopharynx and oropharynx. The lesion extended to the soft palate and the adjacent parapharyngeal and masticator spaces and bulged into the airway. It appeared slightly hyperintense relative to muscle on both short TR/TE (533.3/16) and long TR/TE (2500/80) images (Figs. 1A and 1B) and enhanced slightly after administration of IV gadopentetate dimeglumine (Fig. 1C). The larynx, hypopharynx, and ipsilateral base of the tongue were not involved. No enlargement of lymph nodes was detected. The tumor was resected without complication. Histopathologic examination showed adult-type extra-cardiac rhabdomyoma.

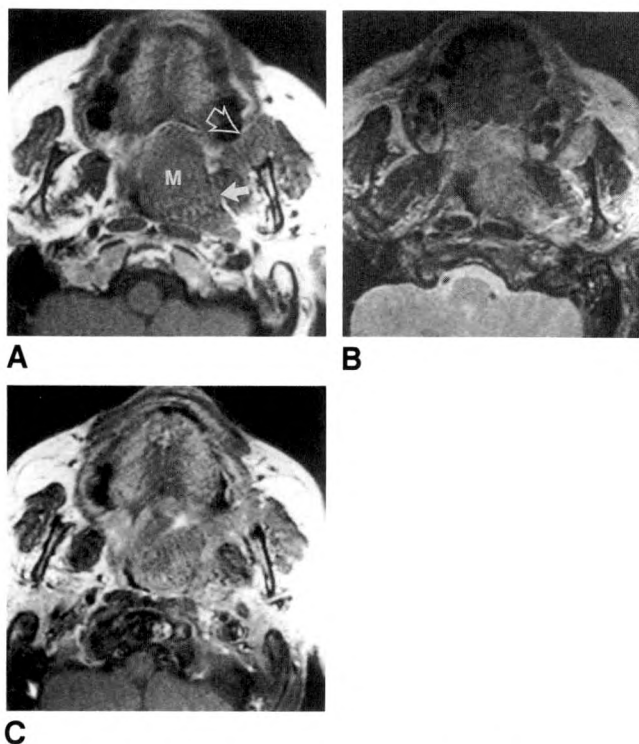


Fig. 1.—Recurrent pharyngeal rhabdomyoma in an adult.

A, Short TR/TE (533.3/16) MR image shows large, well-defined, homogeneous mass lesion (M) involving left lateral wall of oropharynx. Mass extends into adjacent parapharyngeal (solid arrow) and masticator spaces (open arrow) and bulges into oropharyngeal airway. Mass is slightly hyperintense relative to muscle.

B, Long TR/TE (2500/80) MR image shows lesion is slightly hyperintense relative to muscle.

C, MR image obtained after administration of IV gadopentetate dimeglumine shows mild enhancement of lesion.

Rhabdomyomas are rare benign tumors of skeletal or cardiac muscle. Cardiac rhabdomyomas are the most common type and are considered to be hamartomas, which are often associated with tuberous sclerosis [1, 2]. Extracardiac rhabdomyomas are extremely rare and most likely represent true neoplasms [1]. They are usually solitary and have been divided histologically into adult and fetal types.

The adult type occurs almost exclusively in adults, with a marked male predilection of about 5:1. The tumors involve primarily the head and neck. The oral cavity and oropharynx are the most frequent sites; next are the larynx, neck, and nasopharynx. Macroscopically, the tumors appear lobulated and well encapsulated [1]. Histologically, they are composed of large round to oval cells with granular and eosinophilic cytoplasm containing peripheral glycogen-filled vacuoles. The cell nuclei are eccentric. Cross-striations are an essential feature for diagnosis [2]. The fetal type of extracardiac rhabdomyoma occurs mainly in children 3 years old and younger, with a male predominance. The tumors are usually found subcutaneously in the head and neck, most frequently in the posterior auricular area [1, 3]. Fetal-type rhabdomyomas may arise in adults, particularly in the vulvovaginal region. Macroscopically, the tumors are not encapsulated and appear well circumscribed. Histologically, they are composed of spindle fetal myoblasts with various degrees of skeletal differentiation [1].

Extracardiac rhabdomyomas are well-circumscribed nonenhancing tumors that appear isodense with muscle on CT [4]. In our case, the tumor was slightly hyperintense relative to muscle on both short and long TR/TE spin-echo MR images. In addition, slight enhancement of the rhabdomyoma occurred after the administration of contrast material.

The only treatment for extracardiac rhabdomyoma is complete excision [1–3]. Recurrence is rare and is thought to be associated with incomplete resection. In our case, the recurrence became clinically obvious 25 years after the initial surgery. To our knowledge, this is the longest reported period between the initial excision of rhabdomyoma and its recurrence. No known case of benign rhabdomyoma has turned malignant.

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Review of Current Literature

Initials and addresses of corresponding authors are provided in parentheses for each article so that the reader can obtain reprints directly. Abstracts are printed verbatim from each journal.

The New England Journal of Medicine

Magnetic resonance imaging of angiographically occult runoff vessels in peripheral arterial occlusive disease. Owen RS, Carpenter JP, Baum RA, Perloff LJ, Cope C (CC, Dept. of Radiology, Hospital of the University of Pennsylvania, 3400 Spruce St., Philadelphia, PA 19104). *N Engl J Med* 326(24):1577-1581, June 1992

Background. Bypass grafting to arteries of the lower leg has become standard surgical management of advanced peripheral vascular disease. Its success depends on identifying suitable distal vessels. Preoperative preparation includes imaging of the arteries of the lower leg, usually by conventional contrast arteriography. An alternative procedure, magnetic resonance (MR) angiography, has been successfully employed in patients with various cardiovascular diseases, but its possible value in patients with peripheral vascular disease has received little attention.

Methods. We used both conventional and MR angiography in preoperative studies of the lower-leg vessels of 23 patients (25 legs) with peripheral arteriosclerosis and arterial insufficiency, and developed independent therapeutic plans based on the information provided by each technique. When the plans differed, the interventional procedure judged more likely to save the limb was performed. The findings of conventional and MR angiography were verified by intraoperative arteriography, postinterventional arteriography, or direct operative exploration.

Results. MR angiography detected all vessels identified by conventional angiography, whereas conventional arteriography failed to detect 22 percent of the runoff vessels identified by MR angiography. The detection by MR angiography of vessels not identified by conventional angiography altered the surgical management of the disorders of four patients (17 percent) and guided successful bypass procedures.

Conclusions. MR angiography is a noninvasive technique with greater sensitivity than conventional contrast arteriography for detecting distal runoff vessels in patients with peripheral arterial occlusive disease.

The clinical course of pulmonary embolism. Carson JL, Kelley MA, Duff A, et al. (JLC, Division of General Internal Medicine, University of Medicine and Dentistry of New Jersey, Robert Wood Johnson Medical School, 97 Paterson St., New Brunswick, NJ 08903). *N Engl J Med* 326:1240-1245, May 1992

Background. Pulmonary embolism is a potentially fatal disorder. Information about the outcome of clinically recognized pulmonary embolism is sparse, particularly given that new treatments for more seriously ill patients are now available.

Methods. We prospectively followed 399 patients with pulmonary embolism diagnosed by lung scanning and pulmonary angiography, who were enrolled in a multicenter diagnostic trial. We reviewed all hospitalizations, all new investigations of pulmonary embolism, and all deaths among the patients within one year of diagnosis.

Results. Of the 399 patients, 375 (94 percent) received treatment for pulmonary embolism, usually conventional anticoagulation. Only 10 patients (2.5 percent) died of pulmonary embolism; 9 of them had clinically suspected recurrent pulmonary embolism. Clinically apparent pulmonary embolism recurred in 33 patients (8.3 percent), of whom 45 percent died during follow-up.

Ninety-five patients with pulmonary embolism (23.8 percent) died within one year. The conditions associated with these deaths were cancer (relative risk, 3.8; 95 percent confidence interval, 2.3 to 6.4), left-sided congestive heart failure (relative risk, 2.7; 95 percent confidence interval, 1.5 to 4.6), and chronic lung disease (relative risk, 2.2; 95 percent confidence interval, 1.2 to 4.0). The most frequent causes of death in patients with pulmonary embolism were cancer (in 34.7 percent), infection (22.1 percent), and cardiac disease (16.8 percent).

Conclusions. When properly diagnosed and treated, clinically apparent pulmonary embolism was an uncommon cause of death, and it recurred in only a small minority of patients. Most deaths were due to underlying diseases. Patients with pulmonary embolism who had cancer, congestive heart failure, or chronic lung disease had a higher risk of dying within one year than did other patients with pulmonary embolism.

Endoscopic sclerotherapy as compared with endoscopic ligation for bleeding esophageal varices. Stiegmann GV, Goff JS, Michaletz-Onody PA, et al. (GVS, C-313, University of Colorado Health Sciences Center, 4200 E. 9th Ave., Denver, CO 80262). *N Engl J Med* 326(23):1527-1532, 1992

Background. Endoscopic sclerotherapy is an accepted treatment for bleeding esophageal varices, but it is associated with substantial local and systemic complications. Endoscopic ligation, a new form of endoscopic treatment for bleeding varices, may be safer. We compared the effectiveness and safety of the two techniques.

Methods. In this randomized trial we compared endoscopic sclerotherapy and endoscopic ligation in 129 patients with cirrhosis who had proved bleeding from esophageal varices. Sixty-five patients were treated with sclerotherapy, and 64 with ligation. Initial treatment for acute bleeding was followed by elective retreatment to eradicate varices. The patients were followed for a mean of 10 months, during which we determined the incidence of complications and recurrences

of bleeding, the number of treatments needed to eradicate varices, and survival.

Results. Active bleeding at the first treatment was controlled by sclerotherapy in 10 of 13 patients (77 percent) and by ligation in 12 of 14 patients (86 percent). Slightly more sclerotherapy-treated patients had recurrent hemorrhage during the study (48 percent vs. 36 percent for the ligation-treated patients, $P = 0.072$). The eradication of varices required a lower mean ($\pm$ SD) number of treatments with ligation (4 ± 2 vs. 5 ± 2 , $P = 0.056$) than with sclerotherapy. The mortality rate was significantly higher in the sclerotherapy group (45 percent vs. 28 percent, $P = 0.041$), as was the rate of complications (22 percent vs. 2 percent, $P < 0.001$). The complications of sclerotherapy were predominantly esophageal strictures, pneumonias, and other infections.

Conclusions. Patients with cirrhosis who have bleeding esophageal varices have fewer treatment-related complications and better survival rates when they are treated by esophageal ligation than when they are treated by sclerotherapy.

Gastroenterology

Towards a relatively inexpensive, noninvasive, accurate test for colonic motility disorders. Camilleri M, Zinsmeister AR (MC, Gastroenterology Research Unit, Mayo Clinic and Mayo Foundation, Rochester, MN). *Gastroenterology* 103:36-42, 1992

Currently available clinical tests of colonic transit, such as the radiopaque marker method, are useful to detect delayed transit but may be less sensitive for rapid transit. The aim of this study was to develop a relatively inexpensive, noninvasive, accurate test of colonic transit using selected scintigraphic observations within the first 24 hours after ingestion of a pH-sensitive, methacrylate-coated, delayed-release capsule containing ^{111}In -labeled resin pellets. The authors' previously published colonic transit data on 22 healthy subjects, 9 patients with diarrhea-predominant irritable bowel syndrome, and 7 patients with idiopathic constipation and previously unpublished data on 4 patients with carcinoid diarrhea were analyzed. A logistic discriminant analysis was used to estimate the sensitivity and specificity of selected combinations or simple summaries of transit. Among combined transit summaries, the emptying rate of the proximal colon was significantly different between healthy and constipation groups; the geometric center of isotope in the colon at 4 hours was significantly greater in the diarrhea group than in healthy controls; the geometric center at 24 hours was significantly lower in the constipation group than in the other two groups. From the logistic discriminant analysis, simple summaries of transit also had significant discriminant value; these included the isotopic contents in the ascending, transverse, and descending colon at 4 hours and the counts in the ascending and transverse colon and stool at 24 hours. At 90% sensitivity, the specificity of the transverse colon counts at 4 hours was 79%, which is identical to the specificity of the proximal colon emptying rate, both adjusted for age. Thus, quantitation of isotopic counts in colonic regions on scans taken at 4 and 24 hours provides an accurate summary of colonic transit, with acceptable specificity at a high sensitivity in the detection of motility disorders of the colon.

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Pharyngeal clearance during swallowing: a combined manometric and videofluoroscopic study. Kahrilas PJ, Logemann JA, Shezhang L, Ergun GA (PJK, Dept. of Medicine, Northwestern University, Chicago, IL). *Gastroenterology* 103:128-136, 1992

The deglutitive pharyngeal contraction was analyzed using simultaneous videofluoroscopic and manometric studies of eight volunteers. Anterior, posterior, and longitudinal movements of the pharyngeal surfaces, relative to the cervical vertebrae, were measured during swallows of 5 and 10 mL of liquid barium. Profound pharyngeal shortening during bolus transit through the pharynx eliminated access to the larynx and elevated the upper esophageal sphincter to within 1.5 cm of the retrolingual pharynx. Bolus head movement through

the pharynx preceded the propagated pharyngeal contraction and registered manometrically as a slight intrabolus pressure before the major pressure complex. Contraction in the horizontal plane began after bolus head transit and culminated with stripping of the bolus tail through the pharynx. Prolonged upper sphincter opening with the larger-volume swallows resulted from a delayed onset rather than altered propagation of the horizontal pharyngeal contraction. It is concluded that the propagated pharyngeal contraction facilitates pharyngeal clearance but has a minimal role in the process of bolus propulsion during swallowing. The propagated contraction works in concert with profound pharyngeal shortening to minimize hypopharyngeal residue after a swallow.

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The Journal of Bone and Joint Surgery

The prevalence of seropositivity for human immunodeficiency virus in patients who have severe trauma. Behrens JJ, Stannard JP, Bucknell AL (JPS, 5123 Cabin Lake, San Antonio, TX 78244). *J Bone Joint Surg [Am]* 74-A(5):641-645, June 1992

Patients who have severe trauma have been reported to have a substantially increased rate of seropositivity for human immunodeficiency virus when compared with the general population. We reviewed the records of 1226 consecutive Code-3 trauma patients who were treated at our institution in San Antonio, Texas, between 1987 and 1989. All of the patients had serum drawn to be tested for the human immunodeficiency virus. In contrast with previously published studies, only 0.8 per cent of these trauma patients were seropositive. There was no appreciable difference between the prevalence of seropositivity in patients who sustained blunt trauma and those who sustained penetrating trauma. Exposure to human immunodeficiency virus for medical personnel who care for trauma patients remains a concern, but the risk may be lower than previously reported.

Clinical Orthopaedics and Related Research

Magnetic resonance imaging in diagnosis of transient osteoporosis of the hip. Potter H, Moran M, Schneider R, Bansal M, Sherman C, Markisz J (RS, The Hospital for Special Surgery, 535 E. 70th St., New York, NY 10021). *Clin Orthop* 280:223-229, July 1992

The results of magnetic resonance (MR) imaging in six patients with transient osteoporosis of the hip were reviewed. Short TR/TE (repetition time/echo time) images demonstrated diffusely decreased signal intensity in the femoral head and intracapsular region of the femoral neck. Increased signal intensity was noted with progressive T2 weighting. Bone biopsies were performed in four patients. Histologic findings were nonspecific and included fat necrosis, marrow edema, increased bone resorption, and reactive bone formation. Repeat MR scans in two patients, performed six and eight months after the initial scans, showed an almost complete return to normal marrow signal. All patients became asymptomatic without bony deformity. In the appropriate clinical setting, MR scanning can aid in the diagnosis of transient osteoporosis as the cause of a painful hip.

The Journal of Pediatrics

Contralateral renal abnormalities in multicystic-dysplastic kidney disease. Atiyeh B, Husmann D, Baum M (MB, University of Texas Southwestern Medical Center, 5323 Harry Hines Blvd., Dallas, TX 75235-9063). *J Pediatr* 121:65-67, 1992

Multicystic-dysplastic kidney (MCDK) disease has been associated with contralateral genitourinary tract abnormalities; however, neither the nature nor the prevalence of the contralateral renal lesion has been delineated. We retrospectively studied patients with MCDK disease to determine the prevalence of contralateral renal abnormal-

ities and of other urologic anomalies. Forty-nine patients, ranging in age from neonates to 6 years, were examined by renal ultrasonography, excretory urography or nuclear medicine scanning, and voiding cystourethrography; 51% of the patients had an associated urologic abnormality. The abnormality was contralateral to the MCDK in 19 patients (39%), ipsilateral in 3 patients (6%), and involved the bladder wall in 3 patients (6%). The most common contralateral genitourinary tract abnormality was vesicoureteral reflux (18%) followed by ureteropelvic junction obstruction (12%). We conclude that urologic anomalies are common in patients with MCDK disease; contralateral vesicoureteral reflux is the most common abnormality identified.

Journal of Ultrasound in Medicine

Placenta accreta: prospective sonographic diagnosis in patients with placenta previa and prior cesarean section. Finberg HJ,

Williams JW (HJF, Diagnostic Ultrasound, Phoenix Perinatal Associates, 1300 N. 12th St., #320, Phoenix, AZ 85006). *J Ultrasound Med* 11:333-343, July 1992

A prospective evaluation for possible placenta accreta was performed in 34 patients with placenta previa and a history of one or more cesarean sections. Sonographic criteria used included (1) loss of the normal hypoechoic retroplacental myometrial zone, (2) thinning or disruption of the hyperechoic uterine serosa-bladder interface, and (3) presence of focal exophytic masses. Of 18 patients with positive sonographic results, 14 had proof of placenta accreta and 16 of the patients underwent hysterectomy. Of 16 patients with negative sonographic results, only one had placenta accreta, and two patients required hysterectomy. Presence of numerous intraplacental vascular lacunae appears to be an additional risk criterion for placenta accreta, separate from the other criteria listed above.

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News

Advanced Seminars in Diagnostic Imaging

The Dept. of Radiology, University of California, San Diego, is sponsoring Advanced Seminars in Diagnostic Imaging, Jan. 13-15, Feb. 24-27, and April 15-17, 1993, at the Ritz-Carlton Resort Hotel, Laguna Niguel, CA. Program director: David S. Feigin. Category 1 credit: January and April courses, 15 hr; February course, 20 hr. Fee (January and April/February): physicians, \$400/\$500; residents, fellows, and technologists, \$300/\$300. Information: Dawne Ryals, Ryals and Associates, P. O. Box 1925, Roswell, GA 30077-1925; telephone: (404) 641-9773; fax: (404) 552-9859.

Seminars in MRI

Loyola University Chicago is sponsoring Seminars in MRI, Jan. 23-30, 1993, at Marriott's Mark Resort and Conference Center, Vail, CO. The program will concentrate on the common and complex problems encountered in MR imaging of the body and neurologic system. Category 1 credit: 28 hr. Fee: \$500. Information: Division of Continuing Medical Education, Loyola University Chicago, Stritch School of Medicine, 2160 S. First Ave., Maywood, IL 60153; (708) 216-5317.

Big Sky Radiology Conference

The Dept. of Radiology, University of Wisconsin-Madison, is sponsoring the 17th annual Big Sky Radiology Conference, Jan. 31-Feb. 4, 1993, at the Huntley Lodge, Big Sky, MT. Topics to be considered include CT, sonography, MR imaging, and MR angiography of the head, neck, and body. Course director: Virgil B. Graves. Guest faculty: B. Carroll, N. R. Dunnick, R. B. Lufkin, A. J. Megibow, and R. A. Zimmerman. Category 1 credit: 17 hr. Fee: physicians, \$400; residents, \$200. Information: Sandy Yost or Virgil B. Graves, M.D., Dept. of Radiology E3/311, Clinical Science Center, University of Wisconsin, 600 Highland Ave., Madison, WI 53792-3252; telephone: (608) 263-9179; fax: (608) 263-0876.

Current Topics in Diagnostic Imaging

NYU Medical Center, Post-Graduate Medical School, will present Current Topics in Diagnostic Imaging, Feb. 8-12, 1993, at the Hyatt Regency Cerromar Beach, Puerto Rico. Topics to be covered include CT, MR imaging, imaging of the head and neck, neuroradiology, chest radiology, gastrointestinal radiology, urology, bone and joint radiology, and mammography. Category 1 credit: 22.5 hr. Fee: \$495.

Information: New York University, 550 First Ave., New York, NY 10016; telephone: (212) 263-5295; fax: (212) 263-5293.

Intermountain Imaging Conference

Loyola University Chicago is sponsoring the 14th annual Intermountain Imaging Conference, Feb. 20-27, 1993, at the Silvertree Hotel and Snowmass Conference Center, Snowmass, CO. The program will focus on integrated imaging and the advantages of various radiologic techniques and problem solving. Topics will include CT, MR imaging, and sonography of the chest, abdomen, and pelvis. Special mini-courses will be devoted to obstetric sonography and applications of MR imaging in the neurologic and musculoskeletal systems. Category 1 credit: 28 hr. Fee: \$500. Information: Division of Continuing Medical Education, Loyola University Chicago, Stritch School of Medicine, 2160 S. First Ave., Maywood, IL 60153; (708) 216-5317.

Society of Computed Body Tomography and Magnetic Resonance Annual Course

The 16th annual course of the Society of Computed Body Tomography and Magnetic Resonance will be held March 1-5, 1993, at the Walt Disney World Swan, Lake Buena Vista, FL. The course is a comprehensive practical review of state-of-the-art body CT and MR imaging. CT and MR imaging will be compared with other radiologic studies for assessing extracranial organs. Anatomy, pathology, techniques, indications, advantages, and pitfalls of CT and MR imaging will be covered as well as imaging of the neck, chest, abdomen, pelvis, and musculoskeletal system. The emphasis will be on the needs of practicing radiologists. Category 1 credit: 28 hr. Fee (through Feb. 1, 1993/after Feb. 1, 1993): physicians, \$650/\$695; residents and fellows, \$550/\$595. Information: Society of Computed Body Tomography and Magnetic Resonance, c/o Matrix Meetings, Inc., P. O. Box 1026, Rochester, MN 55903-1026; telephone: (507) 288-5620; fax: (507) 288-0014.

Musculoskeletal Imaging for Orthopedic Surgeons and General Radiologists

Boston University School of Medicine is sponsoring Musculoskeletal Imaging for Orthopedic Surgeons and General Radiologists, March 1-5, 1993, at Frenchman's Reef Hotel, St. Thomas, U.S. Virgin Islands. Course director: Peter D. Franklin. Category 1 credit: 21 hr. Fee: physicians, \$450; residents, \$325. Information: Dept. of

Continuing Medical Education, Boston University School of Medicine, 80 E. Concord St., Boston, MA 02118; (617) 638-4605.

San Diego Postgraduate Magnetic Resonance Imaging Course

The Dept. of Radiology, University of California, San Diego, School of Medicine, is sponsoring the 8th annual San Diego Postgraduate Magnetic Resonance Imaging Course, March 8-12, 1993, at the Hotel Del Coronado, San Diego. The course will highlight the physical basis and clinical applications of MR imaging. Program director: John R. Hesselink. Category 1 credit: 29 hr. (pending). Fee (through Feb. 23, 1993/after Feb. 23, 1993): physicians, \$595/\$645; residents, fellows, nurses, and technologists, \$425/\$475. Information: Dawne Ryals, Ryals and Associates, P. O. Box 1925, Roswell, GA 30077-1925; telephone: (404) 641-9773; fax: (404) 552-9859.

PET and SPECT Imaging of Living Brain Chemistry

Johns Hopkins University, School of Medicine, is sponsoring PET and SPECT Imaging of Living Brain Chemistry, March 10-12, 1993, at the Johns Hopkins Medical Institutions, Baltimore. The purpose of the course is to inform participants about the latest uses of positron emission tomography (PET) and single probe systems for the study of brain function and chemistry. Starting with basic principles, the course will describe clinical problems in neuropsychiatry and how PET and single-photon emission computed tomography can be used to approach solutions. Specific examples of studies in patients will be presented and discussed. Course director: Henry N. Wagner, Jr. Category 1 credit: 18 hr. Fee: physicians, \$495; residents, fellows, and allied health professionals, \$395. Information: Patty Campbell, Program Coordinator, or Julia W. Buchanan, Course Co-director, Johns Hopkins Medical Institutions, Office of Continuing Education, Turner Bldg., 720 Rutland Ave., Baltimore, MD 21205; (410) 955-6046 (PC) or (410) 955-8582 (JWB).

MRI Workshop in Hawaii

The 4th annual MRI Workshop in Hawaii will be presented March 21-26, 1993, at the Kea Lani Hotel, Wailea, Maui, HI. Topics to be considered include diseases of the brain, neck, spine, and musculoskeletal system. New techniques such as fat suppression, MR angiography, kinematic knee studies, and MR arthrography will be presented. Course directors: Marc Coel and R. Bell. Category 1 credit: 37 hr. Fee: \$595. Information: Ms. Susan Block, Dept. of Nuclear Medicine, Queen's Medical Center, 1301 Punchbowl St., Honolulu, HI 96813; (808) 547-4544.

World Association of Sarcoidosis and Other Granulomatous Disorders Meeting

The 2nd meeting of the World Association of Sarcoidosis and Other Granulomatous Disorders will be held in Los Angeles, Sept. 8-11, 1993. Sessions will be devoted to the epidemiology, genetics, immunopathogenesis, and clinical aspects of sarcoidosis and other granulomatous disorders. Information: Dr. Om P. Sharma, Rm. 11-900, Los Angeles County/University of Southern California Medical Center, 1200 N. State St., Los Angeles, CA 90033; telephone: (213) 226-7923; fax: (213) 226-2738.

American Society of Neuroradiology New Officers

The American Society of Neuroradiology elected the following to serve as officers for the 1992-1993 term: president, David Norman; president-elect, Glenn Forbes; vice-president, Robert M. Quencer; secretary, Ruth G. Ramsey; and treasurer, Thomas P. Naidich.

The American Board of Radiology Examinations

Written examinations for the American Board of Radiology (ABR) are scheduled for Sept. 23-24, 1993. Oral examinations will be held at the Executive West Hotel in Louisville, KY, June 7-10, 1993. The ABR will accept applications for admission to the examinations after July 1, but not later than Sept. 30, in the year *preceding* the year in which the examination is to be taken. For application forms and further information: Office of the Executive Director, The American Board of Radiology, 2301 W. Big Beaver Rd., Ste. 625, Troy, MI 48064.

Meeting and Course Review

For the reader's convenience, a summary of upcoming meetings and courses is provided. Detailed listings are given in the *AJR* issue given in parentheses.

Visiting Fellowships in Interventional Radiology, times arranged, Baltimore (Sept)

Preceptorships in Ultrasound, times arranged, Baltimore (Sept)

Current Concepts of Magnetic Resonance, Oct. 29-Nov. 1, Laguna Niguel, CA (Oct)

Interventional Radiology Course, Oct. 30-Nov. 1, San Diego (Aug)

New Orleans Fall Radiology Conference, Oct. 30-Nov. 1, New Orleans (Oct)

Postgraduate Radiology, Nov. 2-6, Naples, FL (Aug)

Dysphagia Research Society Inaugural Meeting, Nov. 6-8, Milwaukee (July)

Advanced Seminars in Diagnostic Imaging, Nov. 11-14, Laguna Niguel, CA (Aug)

MRI Visiting Fellowships at UCLA, Dec. 7-11, Los Angeles (Sept 1991)

CT/MRI Head to Toe, Dec. 14-19, New York City (Oct)

Postgraduate Imaging Seminar, Dec. 28, 1992-Jan. 1, 1993, Maui, HI (Sept)

Holiday Imaging Update, Dec. 28, 1992-Jan. 1, 1993, Aspen, CO (Sept)

The Complete MRI Course, Jan. 4-8, 1993, Maui, HI (Sept)

Musculoskeletal MR Course, Jan 4-8, 1993, Naples, FL (Oct)

Society of Uroradiology Annual Meeting, Jan. 9-15, 1993, Naples, FL (Oct)

Robert D. Moseley, Jr. Award, deadline for submissions, Jan. 15, 1993 (Oct)

Interventional Radiology Update, Jan. 16-17, 1993, Laguna Niguel, CA (Oct)

Society of Gastrointestinal Radiologists Annual Meeting, Jan. 17-22, 1993, Scottsdale, AZ (Sept)

Neuroradiology Update, Jan. 18-20, 1993, Laguna Niguel, CA (Oct)

Breast Imaging Update, Jan. 21-24, 1993, Laguna Niguel, CA (Oct)

Breast Imaging Course, Jan. 25-28, 1993, Naples, FL (Oct)

International Symposium on MR Imaging, Jan. 27-31, 1993, Garmisch-Partenkirchen (Bavaria), Germany (Oct)

Computed Body Tomography 1993—The Cutting Edge, Feb. 4-7, 1993, Orlando, FL (Oct)

U. B. C. Practical Radiology at Whistler, Feb. 6–12, 1993, Whistler/Blackcomb Mountain, B.C. (Oct)

Diagnostic Imaging Update, Feb. 15–19, 1993, Palm Beach, FL (Oct)

Sun Valley Imaging Meeting, Feb. 20–27, 1993, Sun Valley, ID (Oct)

MRI Update 1993, Feb. 22–26, 1993, La Quinta, CA (Oct)

Diagnostic Imaging Update, Feb. 22–26, 1993, Maui, HI (Oct)

Magnetic Resonance Imaging, Feb. 22–26, 1993, Naples, FL (Oct)

Positron Emission Tomography, Feb. 28–March 2, 1993, Dana Point, CA (Oct)

International Diagnostic Course in Davos, March 27–April 2, 1993, Davos, Switzerland (Oct)

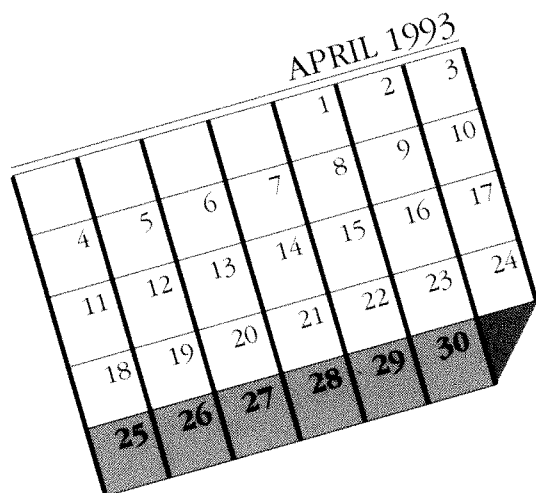
CIRSE and SCVIR Annual Meeting, June 20–25, 1993, Budapest, Hungary (Oct)

AJR carries announcements of courses, symposia, and meetings of interest to its readers if received a minimum of 5 months before the event. There is no charge; receipt of items by the *AJR* Editorial Office is not acknowledged. Submit items for publication typed double-spaced. Provide title, date, location, brief description, sponsor, course directors, fees, category I credit, and address and telephone number for additional information. Faculty from the host institution will not be listed. Guest faculty names will appear **only** if initials are provided. Mail news items to *AJR* Editorial Office, 2223 Avenida de la Playa, Suite 103, La Jolla, CA 92037-3218.

American Roentgen Ray Society

93rd Annual Meeting, San Francisco, CA

Mark Your Calendar Now!



The American Roentgen Ray Society will return to San Francisco in 1993, and plans are already underway for what promises to be an educationally fulfilling and socially enjoyable week in the city by the bay. Look for the San Francisco logo in the next several issues of the *AJR* for updated meeting information. 

Categorical Course

The topic of the 1993 Categorical Course is Ultrasound. A summary of topics and faculty for this course will appear in the February 1993 issue of the *AJR*.

Refresher Courses

Plans are underway to present at least 60 instructional courses on various topics of interest to the radiology community. A summary of these courses will be included in the February *AJR*. Early registration is strongly suggested, as these courses fill up quickly.

Residents' Award Papers

The society offers three cash awards for the best scientific papers prepared by residents in radiology. The President's Award has a cash prize of \$2,000, and there are two Executive Council Awards with a cash prize of \$1,000 each. The winners of these three awards are invited to present their papers during the opening ceremonies at the annual meeting. Papers must be submitted by February 12, 1993, for consideration in this competition. For additional information on these awards, contact the ARRS administrative offices at 1-800-438-2777.

Local Arrangements

The San Francisco area offers many opportunities for sightseeing, shopping and entertainment. Check the February *AJR* for detailed information on local tours developed especially for ARRS meeting attendees.

Registration and Hotel Reservations

All meeting activities will take place in the beautiful new San Francisco Marriott, centrally located on Market Street. The society has negotiated special room rates for meeting attendees, and the February *AJR* will contain meeting registration and hotel reservation forms. As in previous years, early registration is strongly suggested.

Travel

The society will make arrangements with United Airlines and a major car rental firm for preferred rates for meeting attendees. Taking advantage of these special rates benefits both you and the society - you save money on your reservations, and the society receives discounts to send staff and supplies to the meeting. Plan now to check the February issue of the *AJR* for details.

Classified Advertisements

Positions Available

GADSDEN RADIOLOGY ASSOCIATES is a 3-member radiology group seeking a fourth board-certified/eligible radiologist. Gadsden Radiology covers Baptist Memorial Hospital, a 250-bed hospital performing more than 55,000 radiologic exams/yr. All radiologic modalities are available, including state-of-the-art CT, SPECT, nuclear medicine, special procedures, and MRI. Gadsden Radiology Associates also covers their private office, imaging center, and a breast center. Teleradiography is used for call. Gadsden, AL, is a safe, clean city centrally located on the Coosa River approximately 1 hr from Birmingham, 90 min. from Chattanooga, and 2 hrs from Atlanta, GA. Salary and vacation are excellent. Health insurance and malpractice is paid. Interested candidates contact Homer A. Spencer, M.D., 401 Bay Street, Gadsden, AL 35999; (205) 543-3200, or fax (205) 546-7908. 7-1ap

CENTRAL WISCONSIN—Established radiology group in independent practice is seeking 2 additional radiologists for growing practice in central Wisconsin. All imaging modalities. Competitive first yr salary with full partner status available second yr. Full benefits. Excellent schools, recreation, and quality of life. Contact David E. Enerson, M.D., 900 Illinois Ave., Stevens Point, WI 54481; (715) 346-5140 or Andrew M. Lucas, M.D., 410 Dewey St., Wisconsin Rapids, WI 54495-8080; (715) 423-6060. 11xa

ISRAEL, DIAGNOSTIC RADIOLOGY—Opportunities for 3- to 4-wk or longer working vacations in a number of Israeli medical centers, on a volunteer basis. Positions varied, arrangements flexible. For information contact Jonathan H. Fish, M.D., 1844 San Miguel Dr., #302, Walnut Creek, CA 94596; (510) 947-0560. 8-10xa

PARTNERSHIP POSITION IN PALM SPRINGS, CA—Well-established, 9-member group has openings for 2 board-certified radiologists. A physician with a strong background in MRI is sought as director of the section of MRI. The other position requires a physician with mammography experience to direct imaging in the breast health section of a new comprehensive cancer center. The group covers a 350-bed hospital and 2 offices in a desirable, rapidly expanding area of southern California. MRI facilities include 1.5-T Picker Vista HPQ with MRA package, ViStar imaging computer, and 1.5-T GE Signa. Other equipment includes 3 CT, a Cemax image processor, 2 Acuson color-flow Doppler ultrasound, 4 nuclear cameras including 2 SPECT, and all other diagnostic modalities. Ground has just been broken on a new 25,000 sq. ft. radiology wing, which will be furnished with state-of-the-art equipment. New trauma center, cancer center, and rehab hospital being built. Excellent compensation and benefits package leading to full partnership. Beaches and large-city amenities of Los Angeles only 2 hr away. Year-round sunny weather. Ample free time to enjoy southern California and the unparalleled recreational opportunities offered by the resort community of Palm Springs. Direct inquiries to Curtis E. Manning, M.D., Desert Hospital, Dept. of Radiology, 1150 N. Indian Canyon Dr., Palm Springs, CA 92262. 11xa

FAIRBANKS, AK—Four diagnostic radiologists seek fifth partner for diversified practice including general radiology, ultrasound, nuclear medicine, MRI (GE 1.5-T), and CT (GE 9800). Hospital and office practice. Desirable life style advantages in a university town. Unlimited access to the outdoors. Excellent salary, benefits, retirement, and vacation. One yr to full partnership. Contact Douglas Hutchinson, M.D., 1919 Lathrop #5, Fairbanks, AK 99701; (907) 452-5092. 8-1ap

SUPERB PARTNERSHIP POSITION IN LAS VEGAS—Rapidly expanding 7-member group practice covering 2 full-service imaging centers and a small hospital has an immediate opening. We are looking for an additional board-certified radiologist with an uncommon dedication to excellence in patient care. Our outpatient facilities include 2 MR, 2 CT, angio with a 4-bed recovery area, 5 ultrasound, 5 mammography, 3 SPECT, plus R&F. This is an excellent opportunity for a partnership position with a well-respected group in a growing community. Please send CV to Dr. Mark Winkler, SDMI, 2950 S. Maryland Pkwy., Las Vegas, NV 89109. 3-2ap

SAN ANTONIO, TEXAS—Large group covering multiple hospitals and outpatient facilities seeks radiologists with angiography skills. Send CV to Search Committee, M&S X-Ray Associates, P.O. Box 15920, San Antonio, TX 78212-9510. 7-12ap

SOUTH CENTRAL FLORIDA—Immediate opening for board-certified (or eligible with intention to certify), Florida licensed general diagnostic radiologist. Four radiologists are now covering 3 hospitals totaling 250 beds as well as private diagnostic office with mammography. Onsite MRI at 1 hospital and mobile unit at another. Expertise in all modalities including interventional and angiography. Competitive package including early partnership. Send CV to Lawrence S. Ross, M.D., Radiology Consultants, P.A., 114 Medical Center, Sebring, FL 33870. 11xa

CENTRAL NEW JERSEY, IMMEDIATE OPENING—Full-time and part-time radiologists with fellowship training or equivalent experience in vascular/interventional and/or in MR imaging to join 6-member group. Must be willing to do other aspects of diagnostic radiology, mammography, ultrasound, CT, and nuclear medicine. Practice includes a 340-bed community hospital, a private radiology office, and an MRI facility. Area is within a 10-mi. radius of Princeton and is near New York City and Philadelphia. Competitive salary, excellent benefits, and partnership opportunity. Send CV or call Margaret M. Beck, Business Manager, 2127 Hamilton Ave., Trenton, NJ 08619; (609) 587-9410. 11xa

NW ROCKY MOUNTAINS—Highly respected 8-person group with strong subspecialty interests seeks highly qualified radiologist. Fellowship or academic experience preferred. Body imaging/MRI or nuclear medicine with boards or ABR special competency strongly desired. Position includes all aspects of radiology. Practice is located in Boise, ID, which has many recreational and cultural amenities. Reply to Paul Traugbber, M.D., or J. Tim Hall, M.D., Dept. of Radiology, St. Alphonsus Regional Medical Center, 1055 No. Curtis Rd., Boise, ID 83706; (208) 378-2161. 8-1a

MAINE—BC/BE diagnostic radiologist with MRI and/or interventional skills. Join well-established multidimensional group. Associate leading to partnership. Competitive financial package. Family oriented small city. Business and cultural center. Major university. One hr to coast. Easy access to ski areas. Send CV to New England Health Search, 63 Forest Ave., Orono, ME 04473; (207) 866-5680. 11xa

DIAGNOSTIC RADIOLOGIST with skills in CT, MR, interventional, ultrasound, and nuclear medicine needed to join group of 8 board-certified radiologists. Growing practice in eastern Washington at a 228-bed hospital, a new multi-modality imaging center and 1 private office. Potential for long-term practice is excellent. Top-notch school system, including 3 first-rate universities. Excellent hunting, fishing, boating and skiing. Contact Eric W. Koelsch, N. 5901 Lidgerwood, Ste. 18B, Spokane, WA 99207; (509) 487-1264. 8-1ap

VASCULAR/INTERVENTIONAL RADIOLOGIST—The University of Arizona Dept. of Radiology is recruiting a fellowship-trained vascular/interventional radiologist to join the faculty at the assistant associate professor level. Facilities at the University Hospital (300-bed) and Tucson Veteran's Hospital (300-bed) are state-of-the-art. Income is based on AAMC guidelines, but is negotiable. Contact Gerald D. Pond, M.D., Head, Section of Vascular and Interventional Radiology, University of Arizona Health Sciences Center, Tucson, AZ 85724; (602) 626-6794. Women and minorities are encouraged to apply. The University of Arizona is an EEO/AA employer. Applications will be accepted until position is filled. 11xa

OVERWORKED? Need a higher income and more vacation time? Tired of big city commuting and inner-city crime? Want a better quality of life but still want a professional challenge? We need a BC, capable, motivated radiologist qualified in all phases of diagnostic radiology but with special interest, ability and preferable fellowship training in MR to join a 7-member group of American trained, BC radiologists in 450-bed tertiary-care hospital, located in 125,000 populated city, 1 1/2 hrs from Pittsburgh and 3 1/2 hrs from DC and Baltimore. We do 100,000 exams/yr with state-of-the-art equipment. Generous starting salary and benefit package with complete and equal partnership to follow. If interested, send CV to Jon Abrahams, M.D., Chairman, Dept. of Radiology, Conemaugh Hospital, Johnstown, PA 15905; (814) 536-7226. 9-11ap

PART-TIME RADIOLOGIST—General diagnostic radiology; no call; no angiography; several half days per week; hrs flexible; state-of-the-art equipment; large community hospital, southern Chicago suburb. Interested individuals should contact Peter Kucharski, M.D., Dept. of Radiology, Ingalls Hospital, Harvey, IL 60426; (708) 333-2300, ext. 5600. 9-11ap

DIAGNOSTIC RADIOLOGIST for busy expanding 8 radiologist group in picturesque Gulf Coast community. Must have experience in all aspects of diagnostic radiology including angio/interventional/nuclear and MRI. Contact William Nyman, M.D., P.O. Box 1175, New Port Richey, FL 34656-1175. 10-11a

FULL-TIME BC/BE DIAGNOSTIC RADIOLOGIST needed to replace retiring senior partner in a friendly, cooperative 4-man group in south-central Idaho. 165-bed hospital with GE Signa 1.5-T MR, GE 9800 quick CT, Acuson XP, and good technical staff. General radiology including angio, interventional, and nuclear medicine. Good income and vacation schedule 1 yr to partnership. Nice community with extensive nearby skiing, hunting, fishing, etc., 80 miles from Sun Valley, 4 hrs drive from Yellowstone. Send CV and references to Dr. Evan Thomas, Southern Idaho Radiology, P.O. Box AB, Twin Falls, Idaho 83303. 9-11ap

RESIDENT—Due to an unexpected vacancy, the University of Missouri-Kansas City will have an opening for a 2nd, 3rd, or 4th yr radiology resident, beginning January 2, 1993. The UMKC Radiology Residency program is an accredited program and has been in existence for approximately 7 yrs. Truman Medical Center - West is the primary teaching hospital for the program. Applicants must be eligible for Missouri licensure. Competitive salary and benefits. Please forward your CV and letter of interest to Kenneth Alfieri, M.D., Residency Program Director, Truman Medical Center, Dept. of Radiology, 2301 Holmes, Kansas City, MO 64108. 9-11a

NUCLEAR MEDICINE—RADIOLOGIST—CALIFORNIA—Immediate opening for diagnostic radiologist with nuclear medicine boards or special competency in growing private practice in the San Fernando Valley 20 minutes north of UCLA. Candidate to supervise growth of nuclear medicine dept. in addition to general diagnostic radiology work. Full partnership tract with excellent salary. Practice includes hospital and imaging centers. Group consists of young enthusiastic radiologists all with fellowship training. Equipment includes Sopha Spect nuclear, GE 1.5-T MRI with angio, 2 Acuson ultrasound, Siemens Angiostar specials, and 2 Picker 1200 CT scanners. Send CV to T. Sprague M.D., Holy Cross Medical Center, 15031 Rinaldi St., Mission Hills, CA 91345; fax (818) 898-4451. 9-2ap

IMMEDIATE OPENING—BC/BE diagnostic radiologist to join 8 board certified radiologist incorporated practice covering 3 hospitals with approx. 700-beds and 100+ physician multispecialty clinic. All modalities represented. Must be willing to participate in all aspects of general radiology. Excellent fringe benefit package with competitive salary leading to early shareholder status at modest buy-in. Practice located in Arkansas River Valley. Excellent public and private schools. Send CV or contact June Martin, Business Manager, Radiology Services, P.A., P.O. Box 1827, Fort Smith, AR 72902; (501) 782-5035. 9-11ap

BEAUTIFUL COAST OF MAINE—Excellent opportunity for full- or part-time BC/BE radiologist to work with established radiologist in private practice. Pleasant community, yr-round recreational area, smog free, low crime environment. Fully accredited, multispecialty acute care hospital serving 25,000. All modalities of diagnostic radiology offered. Mobile nuclear medicine and MRI currently being pursued. Approximately 15,000 exams annually. Send CV to Executive Director, Waldo County General Hospital, P.O. Box 287, Belfast, ME 04915; (207) 338-2500. 9-11a

INTERVENTIONAL NEURORADIOLOGIST, COASTAL VIRGINIA—A 32-physician private radiology group which practices in 6 hospitals and several offices is seeking an interventional neuroradiologist who is eligible for senior membership in the American Society of Neuroradiology. The individual's clinical responsibilities would be primarily limited to a 644-bed tertiary-care center with level 1 trauma status. Diagnostic equipment includes 2 state-of-the-art Signa 1.5-T GE MR scanners (4.79 software and angio package), a DFP 60A bi-plane bi-digital 1024 matrix Toshiba DSA system (with digital stereo capabilities), and a Siemens DRH as well as a GE 9800 CT scanner. Some time would be spent at a 250-bed hospital with a Hitachi MRP-5000 0.2-T MR unit and a GE 9800 CT scanner with Hi-Light advantage software. Two (2) year fellowship trained neuroradiologists are already on staff. The practice is affiliated with a medical school and residency program which allows the pursuit of academic interests. The practice is located in a coastal resort area with a temperate climate and all water sports available. Interested persons should send a CV or contact Carl V. Bundschuh, M.D., Director of Neuroradiology and MRI, Medical Center Radiologists, Inc., 6161 Kempsville Circle, Ste. 330, Norfolk, VA 23502; (804) 466-0089. 11xa

MAMMOGRAPHER—Large private multi-hospital group in a coastal city of Virginia seeks a radiologist with special interests in all aspects of mammography. The practice includes a tertiary-care hospital which is affiliated with both a medical school and a radiology residency training program, thereby offering the benefits of both private practice and academics. The position would include directorship of future mammography clinics. Additional aptitude in other aspects of diagnostic radiology with specialized and/or fellowship training preferred. Interested applicants please send CV or inquiries to Medical Center Radiologists, Halifax Building, Ste. 330, 6161 Kempsville Circle, Norfolk, VA 23502; (804) 466-0089. 11xa

INTERVENTIONAL RADIOLOGIST—An opportunity exists for an interventionalist to join a group of 12 board-certified radiologists in their hospital and private practice. Position requires fellowship-trained interventionalist with an interest in diagnostic radiology. The practice is based in a 430-bed community hospital with 2 private offices and a hospital owned satellite facility. Services include 2 MRI units, 2 CT units, 2 SPECT cameras, and a new interventional suite with an established interventional practice. Bethlehem is 1 of 3 cities situated in the Lehigh Valley which is within close proximity of NY and Philadelphia. Contact G. Edward Streubert, M.D., Bethlehem Radiologists Associates, 95 Highland Ave., Ste. 105, Bethlehem, PA 18017. 4-12ap

PART-TIME PEDIATRIC/GENERAL RADIOLOGIST, CENTRAL MASSACHUSETTS—Radiologist sought with special competence in pediatric radiology to join an 11-member group. We serve a 550-bed medical center that includes the regional 40-bed neonatal intensive care unit. Position involves sharing general responsibilities including CT, ultrasound, and mammography. Part-time position may become full-time. Please send CV to Richard Danford, M.D., Worcester Radiologists, 121 Lincoln St., Worcester, MA 01605; (508) 753-8151. 10-12a

SOUTHEAST PENNSYLVANIA/CENTRAL NEW JERSEY—Established state-of-the-art multi-hospital and private office practice seeks diagnostic radiologist with interest in all aspects of general radiology. Also seeks individual with subspecialty expertise in angio/interventional or nuclear medicine. Full or part time position. Excellent access to Philadelphia and NYC areas. Send CV to S. Meshkov, M.D., 838 W. State St., Trenton, N.J. 08618. 9-11a

DIAGNOSTIC RADIOLOGIST, COASTAL DOWNEAST MAINE—We'd rather pay recruiting fee to you than to agency. Call for details. Opening for BC/BE radiologist at progressive small rural hospital; college community. Solid financial opportunity. Will tailor arrangements to fit candidate's desire. Contact administration, Down East Community Hospital, Machias, ME 04654; (207) 255-3356. 9-12ap

ULTRASOUND/CT/MRI—Opportunity for board-certified radiologist specializing in ultrasound, body CT, and body MRI to pursue academic career at the New York Hospital-Cornell Medical Center. Dept. provides state-of-the-art equipment, including Acuson and ATL ultrasound, GE 9800 CT, and GE Signa 1.5-T MR. Wide variety of ultrasound examinations include abdominal, OB/GYN, color Doppler, small parts, neonatal head, transvaginal, and transrectal. Prefer candidate with prior fellowship in sectional imaging or ultrasound. Responsibilities include clinical practice, teaching, and research. Position available 7-1-93. Please send CV to Elias Kazam, M.D., Dept. of Radiology, New York Hospital-Cornell Medical Center, 525 E. 68th St., New York, NY 10021. 10-1a

DIAGNOSTIC RADIOLOGIST WITH FELLOWSHIP TRAINING OR SPECIAL INTEREST/TRAINING—We are seeking board-certified individuals to add depth in certain areas of our practice. If you are currently looking for a change in employment, or if you will complete a fellowship or a residency with special interest/training in 1993 or 1994 in any of the following areas, please contact us, vascular interventional, musculoskeletal, ultrasound, neuroradiology. The group is based in Bloomington, Indiana, a beautiful big 10 university community of 50,000+ population, 1 hr from major metro area. Ten diagnostic radiologists servicing 2 hospitals, 1 outpatient center and other sites. Primary hospital has state-of-the-art equipment including 1.5-T MR. Send CV to, or contact, Phil Russell, P.O. Box 4366, Bloomington, IN 47402-4366; (812) 334-8948. 10-12ap

GENERAL RADIOLOGY—Board-certified radiologist with mammographic experience for outpatient facility at the New York Hospital-Cornell University Medical College. The dept. provides 2 state-of-the-art (GE-CGR) mammographic units, an Acuson ultrasound, modern fluoroscopic and radiographic multi-room facility and access to GE Signa 1.5-T MR. Responsibilities include clinical practice, resident and medical student teaching and academic programs. Facility is accredited by ACR in mammography. Qualification for ACR mammographic certification required. Please send CV to Michael D. F. Deck, M.D., Acting Chairman, Dept. of Radiology, The New York Hospital-Cornell University Medical Center, 525 E. 68th St., New York, NY 10021 AA/EEO 11-1a

PART-TIME/LOCUM TENENS DIAGNOSTIC RADIOLOGIST NEAR NORTH CAROLINA COAST—High quality, amiable, hospital-based 2-man practice seeks well-trained BC/BE radiologist. Practice encompasses all imaging modalities but expertise in all modalities not required. Work schedule flexible. One hr to beautiful beaches. Send CV, inquiries to AJR Box # 101.11a

DIAGNOSTIC RADIOLOGIST, NEW MILFORD, CT—A third radiologist is sought for a busy, private practice located in one of the most beautiful areas of Connecticut. We provide the full range of diagnostic services for a modern, well-equipped, community hospital. Choice environment; excellent compensation. Send inquiries and CV to Jules White, M.D., New Milford Hospital, 21 Elm St., New Milford, CT 06776; (203) 355-2611, ext. 235. 10-1a

MINNESOTA—A 34-member multi-specialty group is seeking a BE/BC radiologist to join our expanding physician base. We offer an excellent first year guarantee, vacation, CME time, full health/dental, board study time, money purchase pension/profit sharing trust plans, and more. Beautiful lakes, unspoiled environment and 4 season recreation await you in Virginia, MN. For more information and a video call (800) 377-3290. 10-12ap

IMMEDIATE OPENING for full-time or part-time board-certified/eligible radiologist(s) to join an established 4-man radiology group in the Pacific Northwest. All modalities including MRI. Attractive salary/benefits; partnership opportunity. Community offers quality lifestyle and yr-round recreational opportunities. Send CV to Lynn Ball, Tri-City Radiology, 969 Stevens Dr., Ste. 1-B, Richland, WA 99352. 11-1a

EXCITING RADIOLOGIST OPPORTUNITIES NATIONWIDE!—Now is the time to make your move! ABSOLUTELY NO COST TO YOU. We specialize in RADIOLOGY only, so we understand your needs. Positions from Sunbelt to Northern-most regions. Both salaried and private practice opportunities with top money offered. Utilizing the Snelling Search Computer Network. We know of the positions first and give you the inside tracks! Fax your CV to (214) 258-1092, or mail to Snelling Search Medical Group, 1303 Walnut Hill Lane, Ste. 103, Irving, TX 75038. For information on specific positions call toll free (800) 259-5973. Ask for Roman. 11xa

FACULTY POSITION IN ABDOMINAL IMAGING—Opportunity for board-certified radiologist specializing in abdominal imaging with emphasis on gastrointestinal studies, sonography, and abdominal CT and MR to pursue an academic career at the New York Hospital-Cornell Medical Center. The dept. provides state-of-the-art equipment, including fluoroscopy Acuson and ATL ultrasound, GE 9800 CT, and GE Signa 1.5-T MR. Wide variety of abdominal examinations are done. Prefer candidate with prior fellowship in sectional imaging CT, MR, or ultrasound. Responsibilities include clinical practice, teaching, and research. Position is available July 1, 1992. Send CV to Claudia Henschke, Ph.D., M.D., Director, Starr 9 Division (GI, GU, Chest), Dept. of Radiology, The New York Hospital-Cornell Medical Center 525 E. 68th St., New York, NY 10021. 11-1a

THE LOUISIANA STATE UNIVERSITY MEDICAL CENTER is actively seeking candidates for ultrasound/CT/MRI, bone, chest, nuclear medicine, GI, GU, neuroradiology, angiography/interventional, emergency room, pediatrics and mammography. We are expanding our dept. significantly and are looking for enthusiastic individuals who want to develop a more expansive clinical practice, teaching program and research activities. A perfect opportunity to shape your own section. Applicants must be BE/BC and qualify for licensure in Louisiana. Salaries are competitive nationwide. The university is developing areas of special interest, including a multidisciplinary center for study of neurosciences and plans are underway to purchase all new state-of-the-art equipment. Enjoy the cultural and jazz music of New Orleans. The beaches of Northern Florida are only 3 1/2 hrs away. LSUMC is an AA/EEO. Send CV and 3 references to Jane Clayton, M.D., Acting Chairman, Dept. of Radiology, LSUMC, 1542 Tulane Ave., New Orleans, LA 70112; (504) 568-4647, fax (504) 568-8955. 10-1a

INTERVENTIONAL RADIOLOGIST—Private multispecialty group of 125 physicians with university affiliation in Upper Midwest seeks second board-certified interventional radiologist. Excellent digital angiographic, CT and MR facilities. Superb cooperation with surgical staff. At least 50% interventional with option of some general and/or neuroradiology. Salary equals 90% of partners with full partnership in 1-2 yrs. City of 60,000 population with referral base of 300,000. Send CV to Gerald Smyser, M.D., The United Hospital, Box 6002, Grand Forks, ND 58206-6002; (800) 437-5375. 10-12ap

NEURORADIOLOGIST—A 25-person radiologic group in central New Jersey seeks a fourth neuroradiologist well-versed in all neuroimaging modalities and procedures. Senior member status eligibility in the ASNR is required. Practice includes 2,450-bed hospital, 3 offices, 3 MRI scanners, 5 CT scanners, a radiology residency, and medical student teaching. Send CV to Richard Feinstein, M.D., c/o Kathy McGrath, Radiology Group of New Brunswick, 230 Old Bridge Turnpike, South River, NJ 08882. 10-3a

NEUROLOGICAL CLINIC IN BLACK HILLS OF SOUTH DAKOTA—Unusual opportunity for person interested in MRI practice in small private clinic with the best equipment available. Exceptional situation for one interested in slowing down and practicing in superb environment. MRI expertise is not as essential as is the desire for training. Position available now with compensation flexible and negotiable. Other fields of radiology of personal interest to applicant could be added. Contact J. D. Sabow, M.D., Neurologist, or Alan Baldwin, Director, Imaging Services, 2805 5th St., Ste. 160, Rapid City, SD 57701; (605) 348-7560, fax (605) 348-6449. 10-11a

RADIOLOGIST NEEDED—Thomaston, GA, approximately 60 miles south of Atlanta, GA. Because of future retirement of a senior partner we are looking for a board-certified or eligible partner around June or July 1993. Interested in someone with special interest in imaging (CT & MRI) but at the same time comfortable with angiography and general radiology. Excellent salary and fringe benefits. Contact Ken Morgan, M.D., (706) 647-9745 or 647-1431; Fax (706) 647-9370. 11-2a

RADIOLOGIST/ULTRASOUND—The Dept. of Radiology at the University of Minnesota has a full-time position available in the ultrasound section at the rank of tenure-track assistant professor, tenured associate professor or tenured professor beginning January 16, 1993. At the assistant professor level, minimum requirements are board-certification in radiology, a minimum of 1 yr post residency specialty training or experience in ultrasound, and a demonstrated involvement in quality research accepted or published in peer-reviewed journals. Appointment at the rank of associate professor requires a minimum of 4 yrs post residence experience, a professional distinction in research and writing, and demonstrated effectiveness in teaching and advising. Appointment at the rank of professor requires a minimum of 6 yrs post-residency experience, a national reputation in research, and evidence of leadership in candidate's professional field. Responsibilities will include all facets of diagnostic and interventional sonography, as well as graduate and undergraduate medical instruction. Clinical research will be strongly encouraged and relative performance evaluated on a regular basis. Salary is negotiable and competitive and is dependent on past scholarly productivity and post-M.D. experience. Applicants must be licensed or able to obtain a license to practice medicine in the state of Minnesota before appointment date. Applications will be accepted through December 31, 1992. Send letters to Dr. Janis G. Letourneau, Professor, Dept. of Radiology (Box 292 UMHC), University of Minnesota, 420 Delaware St. S.E., Minneapolis, MN 55455. The University of Minnesota is an equal opportunity educator and employer. 11a

NEURORADIOLOGY, ASST/ASSOC. PROFESSOR—Board-certified neuro-radiologist interested in academic practice with strong clinical and medical student and resident teaching orientation at the New York Hospital-Cornell University Medical College. The dept. provides state-of-the-art equipment with basic research opportunities available through Cornell University Medical College and close affiliation with Memorial Sloan Kettering Cancer Hospital and Rockefeller University. Senior membership of the American Society of Neuroradiology required. Please send CV to Robert Zimmerman, M.D., Dept. of Radiology, New York Hospital-Cornell University Medical Center, 525 E. 68th St., New York, NY 10021; (212) 746-2574, fax (212) 746-8597. AA/EEO. 11-1a

BODY IMAGING—University of Southern California Dept. of Radiology has an opening at assistant professor level for a radiologist with an interest in body imaging. Clinical activity sites include the Los Angeles County/USC Medical Center, a 1,500-bed public hospital, Kenneth Norris Jr. Cancer Hospital and Research Institute, a 60-bed national cancer institute designated comprehensive cancer center and the new USC University Hospital, a 275-bed private facility. Experience or fellowship in body imaging is expected. Board-certification by ABR and eligibility for California licensure is mandatory. Interested applicants should submit CV to Philip W. Ralls, M.D., Chief of Body Imaging and Interventional Radiology, LAC/USC County Hospital, Box 631, 1200 North State St., Los Angeles, CA 90033; (213) 226-7207. University of Southern California is an equal opportunity/affirmative action employer. 11-12a

STATE COLLEGE, PA—Two positions available in private billing, hospital-based group. Mammo-radiologist, BC/BE preferable with fellowship to run ACR accredited breast center. Will replace retiring mammaradiologist currently performing 6,400 exams/yr. Liberal salary and benefits. No call or weekends. General diagnostic radiologist BC/BE, competent in all modalities. Salary and benefit package well above average. Modern, well-equipped hospital including new G.E. 1.5-T Signa Advantage MRI. We offer excellent quality of life in a beautiful central PA college town, home of Penn State U. Send CV to R.A. Rockower, M.D., Dept. of Radiology, Centre Community Hospital, 1800 E. Park Ave., State College, PA 16803 or call (814) 234-6137. 11-1ap

CHIEF—INTERVENTIONAL NEURORADIOLOGIST—University of Southern California Dept. of Radiology seeks an experienced interventional neuroradiologist to develop an ambitious program providing expertise for our new University Hospital, the LAC + USC Medical Center, the Childrens Hospital of Los Angeles, and the Norris Cancer Center. An individual with a large repertoire of diverse procedures is preferable since there is an excellent opportunity to develop an extremely large and versatile clinical services. Additional requirements include board-certification in radiology and a California state medical licensure. Interested parties are encouraged to contact Hervey D. Segali, M.D., Chairman, Neurointerventional Search Committee, USC Medical Center, Box 762, 1200 North State St., Los Angeles, CA 90033; (213) 226-7425 or (213) 681-9019. 11-12a

DIAGNOSTIC RADIOLOGIST, HOUSTON, TX—18-member private practice group seeks BC individual with musculoskeletal or body imaging fellowship. State-of-the-art practice in 1,500-bed teaching hospital with 4 MRI, 5 CT, 7 ultrasound units. Contact P.C. Smith M.D., The Methodist Hospital, 6550 Fannin (ms d-281), Houston, TX 77030. 11-4xa

ULTRASOUND/MAMMOGRAPHY RADIOLOGIST, MINNEAPOLIS—Our 23-person radiology group seeks a BC/BE radiologist with fellowship training in ultrasound and mammography imaging for July 1, 1993. Our practice includes 2 large hospitals and 1 smaller community hospital, and 2 offices with mammography, all financially successful. All imaging modalities except PET available at each hospital. Our practice will soon begin breast biopsies with stereotaxic mammography. Send CV and references including 1 from section chief to Eric L. Bressler, M.D., Suburban Radiologic Consultants, Ltd., 4801 W 81st St., Minneapolis, MN 55437. Inquiries during business hrs. (612) 337-4250. 11-12a

BODY IMAGING RADIOLOGIST, MINNEAPOLIS—Our 23-man radiology group seeks a BC/BE radiologist with fellowship training in body imaging for July 1, 1993. Our practice includes 2 large hospitals and 1 smaller community hospital, all financially successful. All imaging modalities except PET available at each hospital. Candidate would do about 50% body imaging and 50% general radiology. Send CV and references including 1 from Section Chief to Eric L. Bressler, M.D., Suburban Radiologic Consultants, Ltd., 4801 W 81st St., Minneapolis, MN 55437. Inquiries during business hrs. (612) 337-4250. 11-12a

MUSCULOSKELETAL RADIOLOGIST, MINNEAPOLIS—Our 23-man radiology group seeks a BC/BE radiologist with fellowship training in musculoskeletal imaging for July 1, 1993. Our practice includes 2 large hospitals and 1 smaller community hospital, all financially successful. All imaging modalities except PET available at each hospital. Our practice is subspecialized in orthopedic radiology. Candidate would do about 50% orthopedic and 50% general radiology including body imaging. Send CV and references including 1 from section chief to Eric L. Bressler, M.D., Suburban Radiologic Consultants, Ltd., 4801 W 81st St., Minneapolis, MN 55137. Inquiries during business hrs. (612) 337-4250. 11-12a

ABDOMINAL IMAGING RADIOLOGIST—Temple University Hospital and School of Medicine is seeking a board-certified radiologist with fellowship training in abdominal imaging to serve in the section of abdominal imaging. This is a faculty position at the rank of assistant professor. The candidate should have strong clinical skills in CT, MRI, ultrasound, gastrointestinal radiology and urography. The position involves major teaching responsibilities for both residents and medical students. Candidates with established research support would be preferred. Send cover letter/CV to Francis J. Shea, M.D., Professor and Deputy Chairperson, SmithKline Beecham, Dept. of Diagnostic Imaging, Temple University Hospital, 3401 N. Broad St., Philadelphia, PA 19140. Temple University Hospital is an affirmative action/equal opportunity employer. 11a

TRAUMA RADIOLOGIST—The State University of New York Health Science Center at Brooklyn seeks to add a board-certified/eligible radiologist to join the Division of Traumatology at Kings County Hospital Center, a 1,300-bed tertiary facility/Level I Trauma Center with an international reputation in trauma services. The radiologist is an integral member of the trauma service of the dept. of surgery. Opportunities to join ongoing clinical investigations of the use of radiography, CT, angiography/interventional radiology, and ultrasound in the trauma patient are available. Academic rank and salary are commensurate with experience. CV should be addressed to Salvatore J. A. Sclafani, M.D., Dept. of Radiology, Kings County Hospital Center, 451 Clarkson Ave., Brooklyn, NY 11203. An EO/AA employer. 11-1ap

MRI/CT/ULTRASOUND—The State University of New York/Health Science Center at Brooklyn seeks a board-certified/eligible physician to join the faculty in cross-sectional imaging. The medical center is a 1,700-bed facility including Kings County Hospital and the State University Hospital. The medical center performs over 250,000 diagnostic procedures/yr. Currently 4 state-of-the-art CT scanners with a fifth to be installed shortly. A GE Signa was recently installed and a second is planned. Seventeen ultrasound units are in clinical use. Research time and facilities are available. The 2 hospitals are connected with a PACS System via a microwave link. Rank and salary are commensurate with qualifications. CV should be addressed to Joshua A. Becker, M.D., Professor and Chairman, Dept. of Radiology, SUNY/Health Science Center at Brooklyn, 450 Clarkson Ave., Brooklyn, NY 11203. Equal opportunity employer 11-1ap

CARDIOVASCULAR AND INTERVENTIONAL RADIOLOGIST—The State University of New York Health Science Center at Brooklyn seeks a board-certified/eligible radiologist with fellowship training in interventional radiology for a faculty position. The institution is a 1,700-bed facility, including the Kings County and the State University Hospitals. The medical center performs approximately 2,000 diagnostic and interventional procedures including angioplasty, embolization, caval filters, gastrointestinal, genitourinary, and pulmonary interventions. When ongoing renovations are complete, there will be 5 new vascular digital rooms. Research time and facilities are available. Rank and salary are commensurate with qualifications. CV should be addressed to Salvatore J.A. Sclafani, M.D., Kings County Hospital Center, Dept. of Radiology, 451 Clarkson Ave., Brooklyn, NY 11203; (718) 245-4447. An EO/AA. 11-1ap

CHIEF RADIOLOGY—The Dept. of Veterans Affairs Medical Center (VAMC), Des Moines, Iowa, is recruiting for a board-certified radiologist to direct all clinical diagnostic radiologic services in a 163-bed acute medical surgical hospital with a large multispecialty outpatient program and University of Iowa affiliated residencies in medicine and surgery. Applicants should be academically oriented with administrative abilities and demonstrate excellence in teaching patient care. Radiology Service does 26,000 diagnostic exams/yr including CAT scans, nuclear scans, diagnostic ultrasound, and angiography. The dept. recently acquired a Sopha Medical System SPECT scanner, and an ATL Ultramark 9 ultrasound system with high definition imaging will be purchased this yr. Other diagnostic equipment includes a GE 9800 CAT scanner, Siemens Digirion 2, and a Siemens R&F Sireskop 5 room. Des Moines, IA, is a modern progressive community with a prosperous and diversified economy (population, 304,000). National surveys rate public schools in Iowa best in nation. Reasonable housing costs, symphony, opera, and other cultural amenities available. Salary approximately \$120,000. For information contact Dr. Russell Glynn, Chief of Staff, (515) 271-5853. Apply to Personnel Service, VAMC, 3600 30th St., Des Moines, IA 50310. EOE. 11a

THE CREIGHTON UNIVERSITY SCHOOL OF MEDICINE, OMAHA, NE has instituted a search to fill the position of Chair of the Dept. of Radiology. Significant research accomplishments and publications, demonstrated clinical skills, and a commitment to teaching at both the student and resident level are the characteristics which will be most valued by the search committee. The dept. includes a nationally recognized PET center with emphasis on both basic research and clinical applications. Nominations are welcome. Applicants should submit a CV to Michael H. McGuire, M.D., Professor and Chairman, Dept. of Surgery, Radiology Search Committee Chair, Creighton University School of Medicine, 601 N. 30th St., Omaha, NE 68131. Creighton University is an equal opportunity employer. 11a

SAN DIEGO AREA—Four-person radiology group covering 3 hospitals seeks recently trained radiologist as new partner. Must have working knowledge of all modalities, including MRI, angiography, and basic interventional. Anticipated starting date is January 1, 1993. Send CV to Thomas G. Brait, M.D., Paradise Valley Radiology Medical Group, 2400 E. 4th St., National City, CA 91950. 11a

DIAGNOSTIC RADIOLOGIST, NORTHEAST MICHIGAN

—Excellent practice opportunity available for a diagnostic radiologist to commence in the autumn of 1992. Alpena Radiology, P.C., seeks a BC/BE radiologist to complete our 3-man group. We offer excellent income, early partnership and idyllic lifestyle. We require a friendly, hard-working individual who will be a team player. The ability to work well with us and our excellent medical staff is a must. Alpena General Hospital is a modern 175-bed facility located on the shores of Lake Huron. The hospital provides all radiology equipment including: new R&F equipment (G.E.), Siemens CT, SPECT nuclear imaging, color flow Doppler, DSA, ACR accredited mammography. Siemens mobile MRI will commence shortly. The hospital administration is very supportive. The Alpena area is a sportsman's paradise. Sailing, boating, golf, fishing, hunting, skiing, etc. are all minutes away. Our moderate winters and Mediterranean summers are ideal. For more information please contact Steven Zweig, M.D. or James Weeks, M.D., Dept. of Radiology, Alpena General Hospital, 1501 W. Chisholm St., Alpena, MI 49707; (517) 356-7250. 11-1a

RADIOLOGISTS—Miami Veterans Affairs Medical Center is seeking staff radiologist for its teaching hospital affiliated with the University of Miami School of Medicine. Candidates must be board-certified or eligible, with education and experience in CT, MRI, and special procedures. Interested physicians send DC, CV to Personnel Service (05C3/Jean Little) VA Medical Center, 1201 NW 16th St., Miami, FL 33125; (305) 324-4455 ext. 3617. VA is EOE. 11a

PALM SPRINGS AREA, CA—Excellent opportunity for board-certified diagnostic radiologist seeking independent practice environment with support from larger, established radiology group. Experience in general radiology, cross-sectional imaging, nuclear medicine and facility with some interventional techniques required. Attractive salary and vacation options with fast-track to partnership - no buy in. Area provides many recreational activities; its 4-season, high desert climate combines the prairie of the West with the crispness of New England. The air is smog-free and sunny often 350 days/yr. For immediate consideration, call Ginger at 1-800-765-7015 or send CV to MedSearch & Associates, P.O. Box 1259, Groveland, CA 95321. 11a

GENERAL DIAGNOSTIC RADIOLOGIST BOARD-CERTIFIED OR BOARD-ELIGIBLE

—MetroHealth Saint Luke's Medical Center in Cleveland, OH is recruiting general diagnostic radiologists with experience in fluoroscopy, ultrasound, CT, nuclear medicine, MRI, special procedures, interventional, and angiography. MetroHealth Saint Luke's Medical Center, member of MetroHealth System, is a 474-bed University affiliated community teaching hospital with residencies in medicine, surgery, orthopedics, ophthalmology, and obstetrics and gynecology. Radiologists are employed by a professional corporation with excellent benefits including health insurance, malpractice, relocation expense, 6 weeks vacation, 2 weeks CME up to \$5,000 annually, self directed pension, \$200,000 life insurance, and disability insurance. Interested candidates send a CV in confidence to The Rogers Alden Corporation, General Diagnostic Radiologist, P.O. Box 360949, Cleveland, OH 44136 1-800-841-2302. The Rogers Alden Corporation coordinates the recruiting efforts for MHSL. 11a

GENERAL DIAGNOSTIC RADIOLOGIST WITH AN INTEREST IN NUCLEAR MEDICINE, BOARD-CERTIFIED OR BOARD-ELIGIBLE

—MetroHealth Saint Luke's Medical Center in Cleveland, OH, is recruiting a general diagnostic radiologist with an interest in nuclear medicine. Candidate should have experience in fluoroscopy, ultrasound, CT, nuclear medicine, MRI, special procedures, interventional, and angiography. MetroHealth Saint Luke's Medical Center, member of MetroHealth System, is a 474-bed university affiliated community teaching hospital with residencies in medicine, surgery, orthopedics, ophthalmology, and obstetrics and gynecology. Radiologists are employed by a professional corporation with excellent benefits including health insurance, malpractice, relocation expense, 6 weeks vacation, 2 weeks CMR up to \$5,000 annually, self-directed pension, \$200,000 life insurance, and disability insurance. Interested candidates send a CV in confidence to The Rogers Alden Corporation, General Diagnostic Radiologist, P.O. Box 360949, Cleveland, OH 44136; 1-800 841-2302. The Rogers Alden Corporation coordinates the recruiting efforts for MHSL. 11a

MRI/NEURORADIOLOGY/FLORIDA

—Private MRI center seeks board-certified radiologist with MRI experience to oversee and direct diagnostic center. Excellent salary, complete benefit package and excellent recreational activities in growing Ft. Lauderdale community. Reply to Michael Abrahams, M.D., 6971 W. Sunrise Blvd., Plantation, FL 33317; (305) 792-1110. 11-1a

PACIFIC NORTHWEST—Opportunity for BC/BE general diagnostic radiologists to join group of 5 board-certified radiologists. Experience in all modalities desired. Practice includes 2 hospitals and private office in Southern Oregon. Competitive starting salary with early full partnership. Excellent lifestyle with abundant recreational activities from Pacific Coast to Oregon Cascades. Practice in a family-oriented community with natural beauty. Send CV to Larry Strickland, Administrator, Roseburg Radiologists, P.C., P.O. Box 1547, Roseburg, OR 97470; (503) 673-4303.

DIAGNOSTIC RADIOLOGIST—Large private multi-hospital group in a coastal resort area of Virginia is seeking a BC/BE general diagnostic radiologist with proficiency in mammography, ultrasound, CT and general diagnostic radiology. MRI proficiency would also be helpful. The practice includes 5 large hospitals, 2 private offices and several outpatient imaging sites. The practice is also affiliated with a medical school and supports a residency program with 14 residents, thereby offering the benefits of both private practice and the pursuit of academic interests. Fellowship training preferred. Interested applicants should send their CV to Medical Center Radiologists, Inc., Halifax Bldg., Ste. 330, 6161 Kempsville Circle, Norfolk, VA 23502; (804) 466-0089 for further information. 11xa

LOUISIANA—Diagnostic radiologist needed in busy practice including all modalities including vascular and MRI. Excellent benefits, salary, and early partnership. Partner retiring. University community of 100,000 with abundant outdoor recreation. CV to Dan Davidson, M.D., 3000 W. Deborah Dr., Monroe, LA 71201; (318) 388-7810. 11-1a

DIRECTOR RADIOLOGY

—Immediate opening for board-certified radiologist at MetroHealth Saint Luke's Medical Center in Cleveland, OH. MHSL is a University affiliated community teaching hospital with residencies in medicine, surgery, orthopedics, ophthalmology, and obstetrics and gynecology. Qualifications for interested candidates include: Commitment to high quality delivery of health care services to private physicians and patients. Administrative, clinical, and organizational experience. Good communication and leadership skills. Exposure to teaching hospital and new technology development. Evidence of scholarly activity. Interested candidates send a CV in confidence to The Rogers Alden Corporation, Director of Radiology Opportunity, P.O. Box 360949, Cleveland, OH 44136; 1-800-841-2302. The Rogers Alden Corporation coordinates the recruiting efforts for MHSL. 11a

FLORIDA, STAFF RADIOLOGIST

—Opportunity for board-certified/eligible diagnostic radiologist with experience in reading plain films, fluoroscopy, ultrasound, CT, nuclear medicine, and some angiography in radiology service at this GM&S Dept. of Veterans Affairs (VA) Medical Center. Affiliation in surgery with the University of Florida. Excellent employment benefits including 30 days paid vacation and 15 paid days sick leave per yr; liberal life and health insurance benefits; malpractice insurance; and retirement program. Moving expenses paid. Lake City, FL is located in northern Florida with a mild climate yr round. Extensive outdoor recreational activities. Reasonable cost of living, no state income tax, fine schools, local community college, and nearby universities which provide opportunities for continuing education and cultural diversion. Licensure in any state acceptable. Contact or send CV to Richard Parker, M.D., Chief of Radiology, VA Medical Center, Lake City, FL 32055-5898; (904) 755-3016 ext. 2543. An equal opportunity employer. 11-5a

DEPT. OF VETERANS AFFAIRS MEDICAL CENTER, AUGUSTA, GA

is seeking a physician board-eligible/board-certified in radiology. Subspecialty interest in chest, skeletal, GI, CT, ultrasound and MRI radiology is desirable. This 1,142-bed tertiary-care medical center is affiliated with the Medical College of Georgia. Faculty appointment commensurate with qualification and experience. Augusta enjoys a moderate climate, reasonable cost of living, numerous recreational facilities and institutions of higher learning. An equal opportunity employer. For additional information, contact George T. Jamarik, M.D., Chief, Radiology Service, at (706) 823-2236. 11a

CHEST RADIOLOGIST

—Large private multi-hospital group in a coastal resort area of Virginia is seeking a BC/BE general diagnostic radiologist with expertise in pulmonary radiology. The practice includes 5 large hospitals, 2 private offices and several outpatient imaging sites. The practice is also affiliated with a medical school and supports a residency program with 14 residents, thereby offering the benefits of both private practice and the pursuit of academic interests. Fellowship training preferred. Interested applicants should please send their CV to Medical Center Radiologists, Inc., Halifax Bldg., Ste. 330, 6161 Kempsville Circle, Norfolk, VA 23502; (804) 466-0089 for further information. 11xa

PEDIATRIC RADIOLOGISTS—There are 2 full-time faculty positions available in the Dept. of Radiology, Children's Hospital Medical Center, Cincinnati, OH, at academic rank of assistant professor to professor, Dept. of Radiology and Pediatrics, University of Cincinnati College of Medicine, available January 1, 1993. Salary and fringe benefits are highly competitive; salary is based on academic rank and experience. Candidates must be certified in diagnostic radiology by The American Board of Radiology or its equivalent, must have completed a fellowship in pediatric radiology, and must be eligible for active membership in The Society for Pediatric Radiology. Duties include clinical service, teaching, and research. Professional coverage includes conventional radiography, ultrasonography, computed tomography, magnetic resonance imaging, nuclear medicine and digital radiography. Expertise in one particular area of pediatric radiology should not preclude inquiry. The candidate must have a demonstrated interest and qualifications in basic and/or clinical pediatric imaging research. Children's Hospital Medical Center and University of Cincinnati are affirmative action/equal opportunity employers. Address inquiry and CV to Janet L. Strife, M.D., Interim Director, Dept. of Radiology, Children's Hospital Medical Center, Cincinnati, OH 45229-2899; (513) 559-8058. 11a

WATERFRONT, SOUTHERN MICHIGAN—X-ray Associates of Port Huron, MI, is seeking a seventh BC/BE diagnostic radiologist. Our 3 hospital-based practice features nuclear medicine, CT, ultrasound, Doppler, accredited mammography, and general radiography at all sites. Two sites also feature modern cardiovascular suites. A tri-hospital MRI center is featured at the largest site. Interventional skills are desirable but not mandatory. A hardworking, congenial, adaptable individual is an ideal candidate for our team-oriented radiology practice. Salary commensurate with experience, usual benefits, partnership in 2 yrs. Our Canadian-border community of 40,000 has seen rapid commercial growth in spite of the nation-wide recession. We have a small town atmosphere, good local school system, all water related outdoor activities, and most small city amenities. Please send CV to Clare A. Scheurer, M.D., 1002 Tenth Ave., Port Huron, MI 48060. For more information call (313) 987-1237, evenings. 11-4a

THE DEPT. OF RADIOLOGY, MEDICAL COLLEGE OF VIRGINIA/VIRGINIA COMMONWEALTH UNIVERSITY, RICHMOND, VA, seeks candidates for Section Chief (ER radiology, mammography, angio/interventional) and faculty positions in diagnostic radiology (angio/interventional, chest, CT/ultrasound/MR, general radiology, GI, musculoskeletal, neuroradiology) and radiation physics. ABR certification required for section chief positions; ABR certification or eligibility required for faculty positions. MCV is a 1,058-bed facility and a level I trauma center. Individuals should have experience working in a culturally diverse environment. Academic rank and salary commensurate with experience. For position description, or to submit CV, write or phone: A. V. Proto, M.D., Dept. of Radiology, MCV Box 470, Richmond, VA 23298-0470; (804) 786-7212. VCU/MCV is an equal opportunity/affirmative action employer. Women, minorities, and persons with disabilities are encouraged to apply. 11a

DIAGNOSTIC RADIOLOGIST—Mallinckrodt Institute of Radiology, Washington University, seeks an additional board-certified radiologist with academic interest to join 2 radiologists at a satellite hospital of Barnes Hospital in St. Louis. This satellite radiology facility in St. Louis County performs all aspects of diagnostic radiology, including CT, MRI, ultrasound, and nuclear medicine. Equipment is brand new and state-of-the-art. Candidates must be competent in all aspects of diagnostic radiology and must be able to do cross-sectional interventional procedures. Academic rank and salary are dependent on qualifications and previous experience. The Institute is conducting research in teleradiology and out-comes research at the satellite facility. Washington University is an equal opportunity employer, applications from women and minority group members are encouraged. Send CV to R. Gilbert Jost, M.D., Chief of Diagnosis, Mallinckrodt Institute of Radiology, 510 S. Kingshighway Blvd., St. Louis, MO 63110. 11-1ap

NEURORADIOLOGIST FOR FLORIDA GULF COAST—The Dept. of Radiology at the University of South Florida College of Medicine is currently seeking an assistant/associate professor in the dept. of radiology. The candidate should have an M.D. degree and be board-certified in diagnostic radiology. The position is for a neuro-radiologist with fellowship training. This is a combined appointment with the Tampa Veterans Hospital. This may be a tenure earning track position sometime in the future. Competitive salary and generous fringe benefits are derived from both institutions. The location is the beautiful West Coast of Florida with ideal climate. The position involves clinical service, teaching of radiology residents and medical students, and research. Applications or nominations for the position should be addressed to Michael Ver-mess, M.D., Chief, Radiology Service, James A. Haley Veterans' Hospital, 13000 Bruce B. Downs Blvd., Tampa, FL 33612; (813) 972-7514. Application deadline is 12-01-92. The University of South Florida is an affirmative action equal opportunity institution. 11ap

LOUISIANA—Diagnostic radiologist needed in busy practice including all modalities including vascular and MRI. Excellent benefits, salary, and early partnership. Partner retiring. University community of 100,000 with abundant outdoor recreation. CV to Dan Davidson, M.D., 3000 W. Deborah Dr., Monroe, LA 71201; (318) 388-7810. 11-1a

MANCHESTER, KENTUCKY—Excellent opportunity for BC/BE radiologist to take over existing solo practice at rural hospital in east Kentucky. Call sharing available with radiologist in adjacent community. Marion Hughes, Adventist Health System Sunbelt, P.O. Box 1569, Fletcher, NC 28732; (800) 737-2647. 11a

Positions Desired

BOARD-CERTIFIED RADIOLOGIST with over 5 yrs post neurofellowship multimodality experience including over 12,000 CNS, body and extremity MRI examinations. Seeking private practice with opportunities in general radiology, MRI, CT and angio. Prefer locale offering wholesome environment for young children. Respond to Box 10 AJR (address this section) 10-11b

Fellowships and Residencies

FELLOWSHIP IN VASCULAR AND INTERVENTIONAL RADIOLOGY—The University of Arizona is sponsoring a 1-yr fellowship in vascular and interventional radiology beginning July 1, 1994. In-depth clinical experience and training in all aspects of interventional radiology will be offered. Facilities at the University Hospital (300-bed) and Tucson Veterans Hospital (300-bed) are state-of-the-art. Interested applicants should submit a current CV and 3 letters of recommendation (including one from their program director) to Gerald D. Pond, M.D., Head, Section of Vascular and Interventional Radiology, University of Arizona Health Sciences Center, Tucson, AZ 85724. For further information please contact Ruth Kneup at (602) 626-6794. 11xc

FELLOWSHIPS AT THOMAS JEFFERSON UNIVERSITY HOSPITAL—The Dept. of Radiology at Thomas Jefferson University Hospital in Philadelphia offers the following fellowship programs each yr: (1) Ultrasound/CT/MRI—Jefferson's ultrasound division is one of the largest in the world and performs all currently available exams, including obstetric, vascular, lithotripsy, invasive, and endoluminal. We also operate 4 GE 1.5-T MRI units and 3 CT scanners. Contact Barry Goldberg, M.D. regarding this program. (2) Cardiovascular/interventional—This division is housed in a new suite containing Philips angio units with DSA and performs the full range of vascular and nonvascular interventional procedures. Contact Geoffrey Gardiner, Jr., M.D. (3) Neuro/ENT radiology—very active clinical services supply a wealth of material to this division, which is housed in a neurosciences imaging center containing all imaging modalities. Contact Carlos Gonzales, M.D. (4) Breast imaging—Jefferson's new breast-imaging center performs approximately 85 studies/day including ultrasound and needle localizations. Contact Stephen Feig, M.D. (5) Chest—includes biopsies and CT. Contact Robert Steiner, M.D. (6) MRI—a dedicated body MRI program including excellent research opportunities in addition to a large clinical case load. Contact Donald Mitchell, M.D. (7) Ultrasound—a dedicated ultrasound program. Contact Barry Goldberg, M.D. (8) Musculoskeletal—includes MRI of the musculoskeletal system. Contact David Karasick, M.D. All program directors listed above can be contacted at the Dept. of Radiology, Thomas Jefferson University Hospital, Philadelphia, PA 19107. Jefferson is an equal opportunity/affirmative action employer. 11xc

FELLOWSHIP PROGRAM IN INTERVENTIONAL RADIOLOGY—The fellowship offered is a 1-yr training program in interventional radiology. A high volume of studies provides excellent experience for the fellowship training program. The 1-yr appointment is intensive, supervised, and allows for graded responsibility in performance and interpretation of studies including angioplasty, atherectomy, arterial and biliary stents, and all drainage procedures. The fellowship training involves performance of interventional procedures under sonographic and CT guidance as well as fluoroscopy. Inquiries should be addressed to Gordon K. McLean, M.D., Director, Interventional Radiology, The Western Pennsylvania Hospital, 4800 Friendship Ave., Pittsburgh, PA 15224. 5-12c

FELLOWSHIP POSITION: WOMEN'S IMAGING

—High-volume breast imaging (mammography, breast ultrasound, interventional procedures) and ultrasound with emphasis on obstetrical and gynecologic sonography. State-of-the-art mammographic and sonographic equipment including stereotactic table and digital capability. Using stereotactic, ultrasound, or mammographic guidance, all breast interventional procedures are performed, including fine needle and core biopsies, cyst aspirations, pre-surgical localizations, and galactography. Elective time in MRI, CT, and related clinical specialties (surgery, pathology, obstetrics-gynecology). One-year fellowship to start in July 1993. Fellows also have the opportunity to participate in teaching, conference presentations, and research projects, many of which culminate in publications. Inquiries should be addressed to Ellen B. Mendelson, M.D., Chief, Mammography and Women's Imaging, The Western Pennsylvania Hospital, 4800 Friendship Ave., Pittsburgh, PA 15224. 5-12c

ONCORADIOLOGY/MAMMOGRAPHY FELLOWSHIP

—The Dept. of Radiology at the Dana-Farber Cancer Institute and Brigham and Women's Hospital, which are Harvard Medical School affiliates, offers a 1-yr fellowship position beginning July 1, 1993. All imaging modalities involved in the diagnosis, staging, and follow-up of patients with malignant disease are integrated into this program. An additional feature is a concentrated experience in the performance of interventional breast diagnostic procedures. Please contact Jack E. Meyer, M.D., Director of Diagnostic Radiology, Brigham and Women's Hospital and Dana-Farber Cancer Institute, 75 Francis St., Boston, MA 02115; (617) 732-6269. Brigham and Women's Hospital/Dana Farber Cancer Institute/Harvard Medical School is an affirmative action/equal opportunity educator and employer. 5-4c

IMAGING (ULTRASOUND, BODY CT, AND MRI) FELLOWSHIP TO BEGIN JULY 1993

—The Dept. of Radiology at The Western Pennsylvania Hospital (a 578-bed advanced, tertiary-care teaching hospital), Pittsburgh, PA, offers a 1-yr imaging fellowship. The fellowship emphasizes diagnostic ultrasound with rotations in body magnetic resonance imaging and computed body tomography. Examinations in all areas of sonography are performed and include obstetrics and gynecology, vascular/Doppler, abdominal, prostate, pediatrics, breast, and small parts. State-of-the-art equipment in all areas of the dept. Fellows will participate in procedures guided by ultrasound and computed tomography. Fellows have ample opportunity to participate in conference presentations and research projects, many of which culminate in publications. Inquiries should be addressed to Marcela Bohm-Velez, M.D., Director of Imaging Fellowship Program, Dept. of Radiology, The Western Pennsylvania Hospital, 4800 Friendship Ave., Pittsburgh, PA 15224. 5-12c

FELLOWSHIP IN IMAGING/ANGIO-INTERVENTIONAL

—A 1-yr fellowship program at Lehigh Valley Hospital in Allentown, PA is available. LVH is a 514-bed acute care university-affiliated hospital. The fellowship program offers training in CT (head and body), ultrasound, MR, angiography, and interventional radiology. For further information contact Robert Kricun, M.D., Dept. of Radiology, Lehigh Valley Hospital, P.O. Box 689, Allentown, PA 18105-1556. 10-12c

ACCREDITED FELLOWSHIPS IN PEDIATRIC RADIOLOGY AND PEDIATRIC NEURORADIOLOGY

—Dept. of Radiology, Children's Hospital Medical Center, Cincinnati, OH, offers 1- or 2-yr accredited (Residency Review Committee for Radiology of ACGME) fellowships in pediatric radiology beginning July 1, 1994. A 1-yr pediatric neuroradiology fellowship program is also offered and may be taken separately or combined with 1 yr of adult neuroradiology fellowship at the University of Cincinnati Medical Center. Children's Hospital Medical Center (CHMC) is a 355-bed institution. The dept. performs over 105,000 radiological exams/yr in the largest children's hospital and ambulatory practice in the U.S. The dept. has 14 full-time faculty pediatric radiologists, 1 full-time research faculty, 7 fellows, and many resident trainees. Six pediatric radiology and 1 pediatric neuroradiology fellowship positions are available annually. Training includes all aspects of pediatric imaging: neonatal radiology; neuroimaging; musculoskeletal radiology; cardiovascular and thoracic imaging; abdominal imaging; oncologic imaging; ultrasound; nuclear medicine; computed tomography; MRI; and vascular/interventional procedures. The dept. has an active clinical service with state-of-the-art equipment as follows: digital fluoroscopy; Acuson and ATL ultrasound units with Doppler and color flow Doppler capabilities; planar SPECT gamma cameras; GE 9800 Quick CT scanner; 1.5-T GE MRI with spectroscopy, and cardiac catheterization/angiographic suite with digital vascular imaging. The fellowship provides a broad clinical experience in pediatric radiology as well as numerous opportunities to participate in both clinical and basic research. Candidates must be board-certified or board-qualified in diagnostic radiology and must obtain an Ohio medical license. Salary and fringe benefits are highly competitive. Applications are due prior to February 1993 with interviews scheduled during the fall and winter of 1992-93. There are numerous career opportunities in pediatric radiology and pediatric neuroradiology in both academic and private practice settings. To receive more information about the fellowships at CHMC or careers in pediatric radiology, please contact Director, Dept. of Radiology, Children's Hospital Medical Center, Cincinnati, OH 45229-2899; (513) 559-8058. Children's Hospital Medical Center and the University of Cincinnati College of Medicine are affirmative action/equal opportunity employers. 7-1cp

FELLOWSHIP IN VASCULAR/INTERVENTIONAL RADIOLOGY

—The Yale University Dept. of Radiology has an unexpected opening for a third fellowship position starting July 1993. The section has an active clinical service performing a wide range of vascular and interventional procedures including: diagnostic angiography, angioplasty, stenting, atherectomy, infusion therapy, embolotherapy, IVC filter placement, and percutaneous renal, biliary, and abscess management. Additionally, there is an inpatient admitting service and clinic. The fellowship is for 1 yr. Please send CV and 3 letters of recommendation to Jeffrey Pollak, M.D., Section Chief, Dept. of Diagnostic Radiology, Yale University School of Medicine, 333 Cedar St., P.O. Box 3333, New Haven, CT 06501, (203) 785-4746, (203) 785-3024 fax. Yale University is an equal opportunity/affirmative action employer. Applications from women and minority group members are encouraged.

FELLOWSHIP IN ABDOMINAL IMAGING AND INTERVENTIONS

—The Dept. of Radiology, Massachusetts General Hospital and Harvard Medical School, offers a 2-yr fellowship in abdominal imaging and interventional radiology beginning July 1, 1994. Training covers all aspects of abdominal imaging (fluoroscopy, ultrasound, CT and MR) and nonvascular interventions in the GI/GU tract. Ample time is made available for both clinical and laboratory research in the above areas during the second year. Candidates should be ABR-eligible or certified. Address inquiries to Peter R. Mueller, M.D., or Nicholas Papanicolaou, M.D., Dept. of Radiology, Massachusetts General Hospital, Boston, MA 02114. An equal opportunity employer. 9-11c

FELLOWSHIP IN ULTRASOUND AND BODY CT/MRI

—One-yr fellowships in ultrasound and body CT/MRI beginning July 1, 1993, and July 1, 1994, are being offered by the New York Hospital-Cornell Medical Center. The dept. provides state-of-the-art equipment, including Acuson and ATL ultrasound, GE 9800 CT, and Ge Signa 1.5-T MR. Wide variety of ultrasound examinations include abdominal, OB/GYN, color Doppler, small parts, neonatal head, transvaginal, and transrectal. Applicants should be ABR eligible or certified. Send CV to Elias Kazam, M.D., Dept. of Radiology, New York Hospital-Cornell Medical Center, 525 E. 68th St., New York, NY 10021. 10-1c

CARDIAC IMAGING FELLOWSHIP (CLEVELAND CLINIC FOUNDATION)

—The section of cardio-vascular imaging (division of radiology) announces to interested and qualified BC/BE radiologists a 2-yr cardiac imaging fellowship position (July 1, 1994 - June 30, 1996). This fellowship emphasizes integrated diagnostic imaging of acquired and congenital diseases of the heart and thoracic vasculature using non-invasive radiologic techniques (plain-film x-ray, CT, MRI, Nuclear Cardiology including PET) through a balance of practical clinical and research experiences. Research activities are complemented by lectures and technical assistance from the division's biostatistician. Didactic training both in cardiac catheterization/cine cardioangiographic interpretation and in performance/interpretation of echocardiography is coordinated with the dept. of cardiology for clinical and research cross-correlation. Direct all correspondences to Richard D. White, M.D. Head, Section of Cardio-Vascular Imaging, Division of Radiology L-10, Cleveland Clinic Foundation, 9500 Euclid Ave. Cleveland, OH, 44195; (216) 444-2740. 10-1c

FELLOWSHIP POSITIONS

—The Dept. of Radiology of the Brigham and Women's Hospital-Harvard Medical School has 1- or 2-yr fellowship positions in the following areas: (1) cardiovascular and interventional, (2) neuroradiology, (3) CT/ultrasound/MR/interventional, (4) oncoradiology, (5) chest, (6) bone, (7) nuclear medicine, and (8) computer science. For more information, please send CV specifying your area of interest to B. Leonard Holman, M.D., Chairman, Dept. of Radiology, Brigham and Women's Hospital, 75 Francis St., Boston, MA 02115. Harvard Medical School and Brigham and Women's Hospital are equal opportunity, affirmative action employers. 5-4c

FELLOWSHIPS AT ALBANY MEDICAL CENTER

The newly-renovated and equipped Dept. of Radiology at the Albany Medical College and Center in Albany, NY, offers the following fellowship positions each yr: (1) Abdominal Imaging—This fellowship encompasses all aspects of MRI, ultrasound, CT, and other advanced techniques in imaging the abdomen. Four state-of-the-art MRI and 4 CT scanners as well as 5 color Doppler ultrasound units are utilized daily. Contact James C. Peters, M.D. regarding this program. (2) Neuroradiology—This fellowship encompasses the full range of advanced neuro imaging including MRI, CT, angiography, and myelography. Contact William A. Wagle, M.D. (3) Angiography and interventional radiology—Three advanced angiographic suites are utilized daily for a full range of vascular and interventional procedures. Contact Mohammad S. Sarrafzadeh, M.D. All program directors listed above may be contacted at the Dept. of Radiology, A-113, Albany Medical Center, Albany, NY 12208; (518) 445-3277 or contact Matthew D. Rifkin, M.D., Chairman, Dept. of Radiology, A-113, at the above address. Albany Medical Center is an equal opportunity/affirmative action employer. 1-12c

INTEGRATED CHEST RADIOLOGY FELLOWSHIP AT JOHNS HOPKINS UNIVERSITY HOSPITAL

The Dept. of Radiology, Division of Thoracic Imaging, Johns Hopkins University is offering a 1- or 2-yr academically-oriented fellowship in chest radiology. The fellowship offers an integrated experience in cross-sectional imaging including over 4,000 chest CT exams/yr and 1,000 thoracic MRI examinations. Strong research interests in high-resolution computed tomography, magnetic resonance imaging, and interventional thoracic radiology offer the potential candidate an exciting environment to work in. The fellowship is available starting July 1, 1993, or July 1, 1994. Contact Janet E. Kuhlman, M.D., Director of Chest Radiology, Dept. of Radiology, Johns Hopkins Hospital, Baltimore, MD 21287; (410) 955-4419. 10-1cp

INTERVENTIONAL MAMMOGRAPHY AND BREAST IMAGING FELLOWSHIP

The University of Arizona is offering a flexible 1-yr fellowship in interventional mammography and breast imaging beginning July 1993. The section performs more than 14,000 mammograms per/yr and over 500 breast interventional procedures, including percutaneous stereotaxic breast needle biopsy, preoperative localizations, and galactography. Equipment includes 7 state-of-the-art mammographic units and 5 stereotaxic devices. The fellowship will include 20% academic/protected research time and up to 4 months could be spent in other areas of body imaging (CT, ultrasound, or MRI). We have an active research program including clinical, basic science and technology assessment/outcome analysis research related breast imaging. Other benefits include: relocation allowance, office space with computer, and funds to attend national meetings. No "night call" responsibilities. Salary \$38,500. Must be BC/BE. Will need Arizona license upon arrival. For further information please contact, Laurie L. Fajardo, M.D., Director, Mammography and Breast Imaging, University of Arizona, 1501 N. Campbell Ave., Tucson, AZ 85724. Application deadline, January 31, 1993. The University of Arizona is an equal opportunity/affirmative action employer. 10-1a

PEDIATRIC RADIOLOGY, CHILDREN'S HOSPITAL, LOS ANGELES

Four fellowships annually in pediatric radiology with experience in general radiology, fluoroscopy, ultrasound, CT, MR, neuroradiology, angiography, interventional radiology, nuclear radiology and PET. Emphasis on clinical experience, education, and clinical research during training results in a comprehensive experience. One-yr fellowships are offered with an option of an additional year of specialized work. A specific fellowship in pediatric neuroradiology or special emphasis in angiography, interventional radiology is also available. Fellowship is ACGME accredited. CHLA is a 331-bed children's hospital servicing a community of 13 million. The dept. of radiology performs approximately 100,000 studies annually. All pediatric subspecialties are represented with centers in oncology, cardiopulmonary disease, neural sciences, and genetics established as part of the tertiary and quaternary mission of the hospital. Strong emphasis in teaching and training with 98 pediatric residents and over 100 fellows and Ph.D.s in hospital. Research at the CHLA Research Institute. Ten diagnostic, 1 radiation oncology and 1 Ph.D., MR physics faculty are full time in radiology. Dept. is completely equipped with state-of-the-art equipment including a 1.5-T magnet, 3 ultrasound units with color Doppler, and SPECT. For more information contact Beverly P. Wood, M.D., Dept. of Radiology, Children's Hospital Los Angeles, 4650 Sunset Blvd., MS# 81, Los Angeles, CA 90054-0700; (213) 669-5686, fax (213) 666-4655. 10-12c

MR FELLOWSHIPS, IMMEDIATE OPENINGS

The Dept. of Radiology, University of Rochester Medical Center MR fellowship offers a broad range of experience in both body and neuro MR. Associated imaging experience is available with CT. Research opportunities are available. Two 1.5-T G.E. Signa magnets with the latest software are in use and a third is being planned. Three CT units are in use. Eligible applicants must be board-certified or eligible for certification in diagnostic radiology and should be eligible for licensing in the state of New York. Contact Deborah Rubens, M.D., Dept. of Radiology, Box 648, University of Rochester Medical Center, Rochester, NY 14642; (716) 275-8365. EO/AA/M-F. 10-12c

FELLOWSHIP IN BODY IMAGING AND INTERVENTIONAL RADIOLOGY - USC SCHOOL OF MEDICINE

Commencing July 1, 1992, 1-yr fellowship positions for yrs 1992-1993 and 1993-1994 are available for board-certified radiologist to receive fellowship training in MR, CT, ultrasound, and interventional procedures guided by those modalities in the Dept. of Radiology, University of Southern California. This program offers superb training supervised by academically productive faculty in rich clinical setting. Excellent opportunities exist for supervised hands-on-training in MR, MR angiography, CT, CT-guided procedures, ultrasound, including color Doppler sonography and ultrasound-guided procedures. The dept. of radiology has state-of-the-art and prototype equipment in all modalities and offers excellent opportunity to achieve expertise in body imaging and related interventional techniques. Interested candidates should contact Philip W. Rallis, M.D., Chief of Body Imaging and Interventional Radiology, LAC/USC County Hospital, Box 631, 1200 North State St., Los Angeles, CA 90033; (213) 226-7207. USC is an equal opportunity/affirmative action employer. 11-12c

FELLOWSHIPS - IMMEDIATE OPENINGS

The Dept. of Radiology, University of Rochester Medical Center, is offering fellowships in body imaging/interventional, neuroradiology, vascular/interventional radiology, and MR. Eligible applicants must be board-certified or eligible for certification in diagnostic radiology and should be eligible for licensing in the state of New York. Applicants should contact the program directors: MR and Body Imaging/Interventional, Deborah Rubens, M.D.; Neuroradiology, Leena Ketonen, M.D.; Vascular Interventional, Oscar Gutierrez M.D. Program directors can be contacted at the Dept. of Radiology, University of Rochester Medical Center, Box 648, 601 Elmwood Ave., Rochester, NY 14642; (716) 275-5200. EO/AA/M-F. 10-12c.

THE UNIVERSITY OF TEXAS M.D. ANDERSON CANCER CENTER, FELLOWSHIP IN BODY IMAGING AND VASCULAR INTERVENTIONAL RADIOLOGY

The Dept. of Diagnostic Radiology, University of Texas M.D. Anderson Cancer Center, is currently accepting applications for fellowships in body imaging and vascular interventional radiology for academic yrs. July 1993 - June 1994 and July 1994 - June 1995. The dept is equipped with state-of-the-art ultrasonography, computed tomography, magnetic resonance imaging, positron emission tomography, angiography, routing fluoroscopy, and mammography equipments. The fellows will have an opportunity to do clinical study with large number of clinical material seen at the institution and experimental research is available through Dunn Laboratory of Radiological Science. Candidates interested in these positions should write to Chusilp Charnsangavej, M.D., Professor and Deputy Chairman for Academic Affairs, Dept. of Diagnostic Radiology, Box 57, University of Texas M.D. Anderson Cancer Center, 1515 Holcombe Blvd., Houston TX 77030. 11-2c

FELLOWSHIP IN INTERVENTIONAL RADIOLOGY, UNIVERSITY OF SOUTHERN CALIFORNIA SCHOOL OF MEDICINE

Due to increased activity, the dept. of radiology has available 1-yr fellowship positions for the yrs 1992-93 and 1993-94 in interventional radiology beginning July 1, 1992. The interventional practice includes 3 contiguous hospitals. The primary teaching site of the university is the LAC+USC Medical Center, a 1,500-bed public facility. The adjacent Kenneth Norris Cancer Hospital is a 60-bed national cancer institute referral facility with an active interventional practice and the new USC University Hospital, a 275-bed private facility. The practice spans the breadth of interventional radiology with an exceptional experience in trauma and oncologic interventions. Interested candidates should contact Michael Katz, M.D., LAC+USC Medical Center, 1200 N. State St., Radiology, Rm. 3550, Los Angeles, CA 90033; (213) 226-7242. USC is an equal opportunity/affirmative action employer. 11-12c

FELLOWSHIP IN ULTRASOUND, BODY CT AND MRI

July 1, 1994. 1-yr program featuring ultrasound, body CT, body MRI and noninvasive vascular diagnosis. For information and application contact William Zwiebel, M.D., Dept. of Radiology, University of Utah Hospital, Salt Lake City, UT 84132; (801) 581-7553. 4-2c

NEURORADIOLOGY FELLOWSHIP—Two yrs beginning July 1, 1993. Exposure to all aspects of clinical/academic neuroradiology including CT, MRI, interventional procedures, vascular ultrasonography and pediatric neuroradiology. Participation in research and teaching. Send cover letter/CV to Te-Hua Liu, M.D., Director, Neuroradiology Section, Dept. of Diagnostic Imaging, Temple University Hospital, 3401 N. Broad St., Philadelphia, PA 19140. Temple University Hospital is an affirmative action/equal opportunity employer. 11c

VASCULAR/INTERVENTIONAL RADIOLOGY FELLOWSHIP—Temple University Hospital and School of Medicine has available a 1-yr fellowship beginning July 1, 1993. The candidate will have exposure to all areas of vascular and interventional radiology including noninvasive techniques and MRI/A. Approximately 1,100 procedures are performed annually including: vascular/non-vascular stents, TIPSS, transcatheter and percutaneous embolotherapy, extensive endourologic and biliary interventional procedures. Applicants should contact David S. Ball, D.O., Chief, Section of Vascular/Interventional Radiology, Dept. of Diagnostic Imaging, Temple University Hospital, 3401 N. Broad St., Philadelphia, PA 19140. Temple University Hospital and School of Medicine is an affirmative action/equal opportunity employer. 11c

PENN STATE UNIVERSITY, FELLOWSHIP IN CARDIOVASCULAR/INTERVENTIONAL RADIOLOGY—The Pennsylvania State University Dept. of Radiology offers 1- or 2- yr fellowships in cardiovascular/interventional radiology. Fellows will receive training in all aspects of diagnostic and interventional angiography (including neuro and pulmonary angiography), percutaneous and percutaneous/peroral GI interventions, GU interventions, venography, IVC filter placement, embolizations, foreign body retrievals, biopsy, drainage, and stenting procedures. Appointment at the instructor level is required, necessitating a Pennsylvania medical license, University Hospital medical staff privileges, and ABR eligibility (at time of application) and certification (during first program yr). Independent original research is expected and is well supported. The animal research facility is excellent. A dedicated MR research facility with angiographic and spectroscopic capability exists. Both facilities are fully staffed by research associates and faculty and are equipped with state-of-the-art equipment. Eligibility: The fellowship is open to individuals who have completed an accredited residency program in radiology, can obtain a Pennsylvania medical license, and have fulfilled ABR requirements for board-certification/eligibility. Stipend: A generous and competitive salary and benefits package are offered. Academic, biophotographic, and secretarial support are also provided. Applications: Applicants should respond with a letter of interest and current CV. Please direct inquiries and requests for application forms to John F. Cardella, M.D., Assoc. Professor and Chief, Cardiovascular/Interventional Radiology Section, Penn State University/Hershey Medical Center, Box 850, Hershey, PA 17033. Penn State University is an affirmative action, equal opportunity employer; women and minorities are encouraged to apply. 11-1c

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Tutorials/Co

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REVIEW ARTICLES

- 925 Evaluation of congenital heart disease with MR imaging: current and coming attractions. *Fellows KE, Weinberg PM, Baffa JM, Hoffman EA*
- 933 CT of the extraperitoneal space: normal anatomy and fluid collections. *Korobkin M, Silverman PM, Quint LE, Francis IR*
- 943 Color Doppler imaging of the hepatic vasculature. *Grant EG, Schiller VL, Millener P, et al.*

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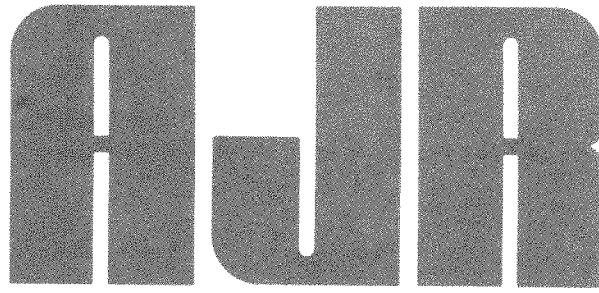
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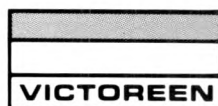
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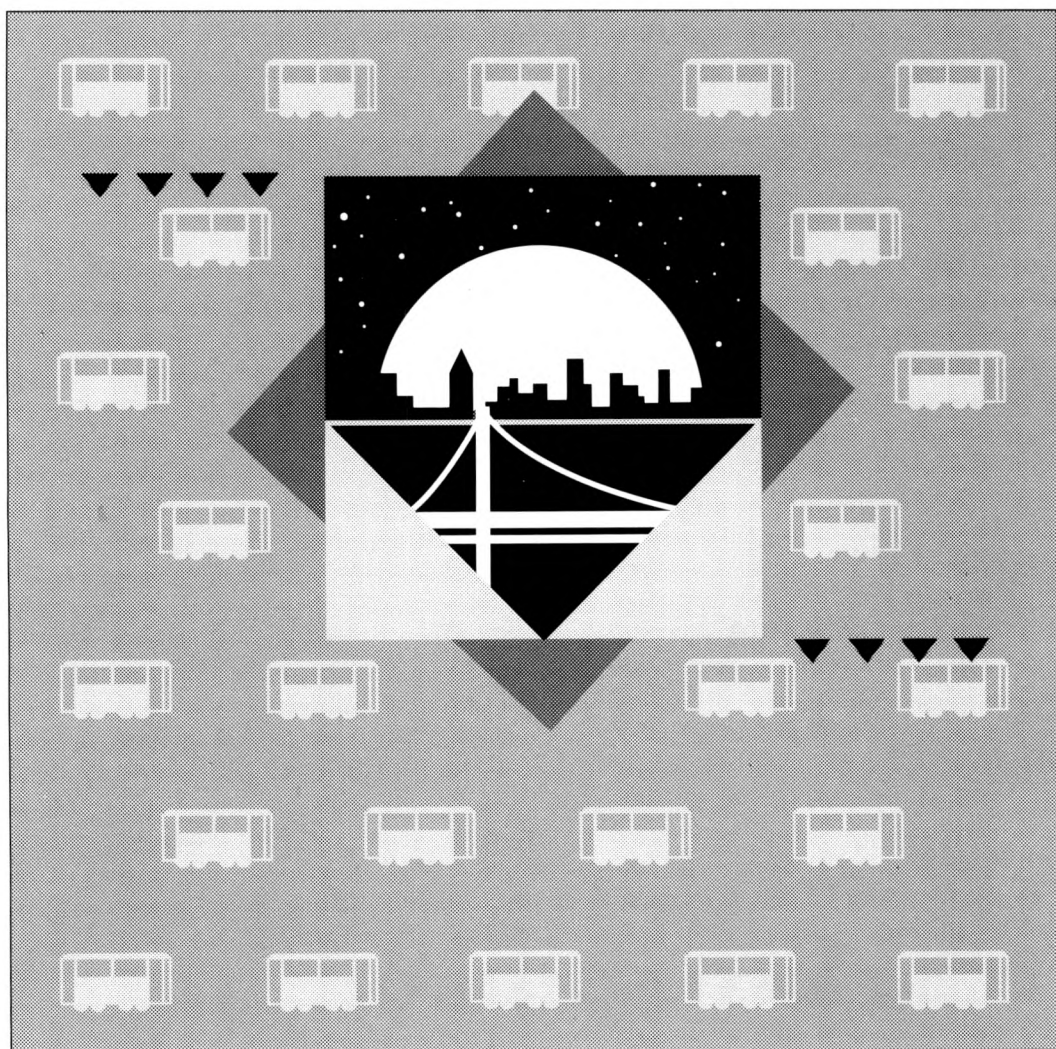


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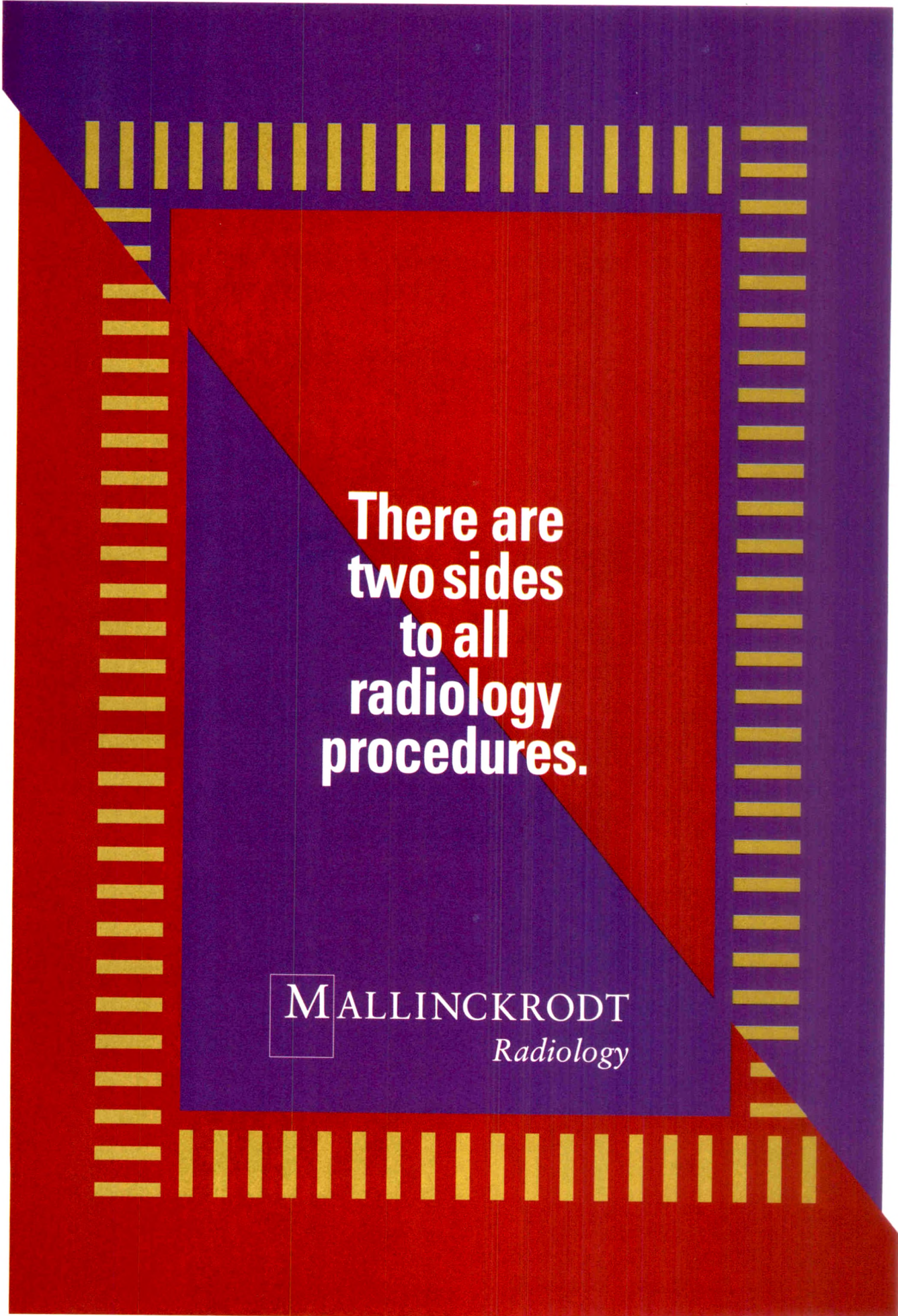
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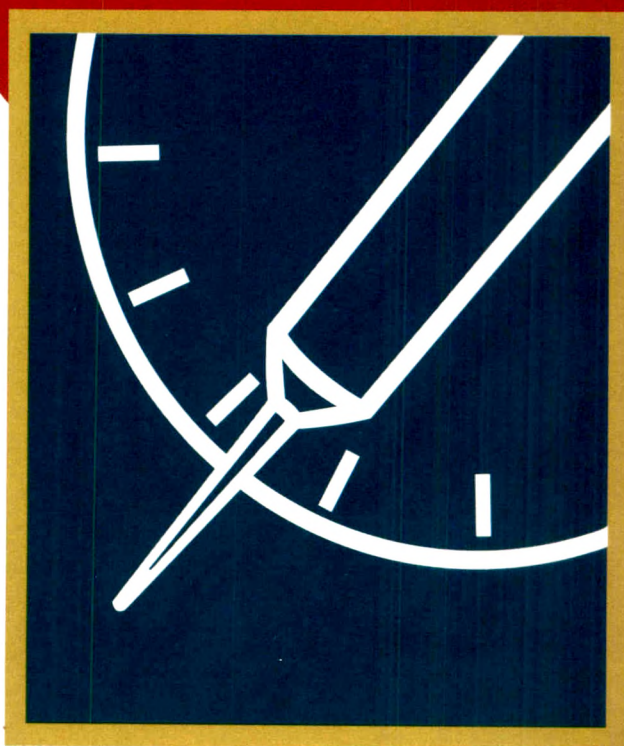
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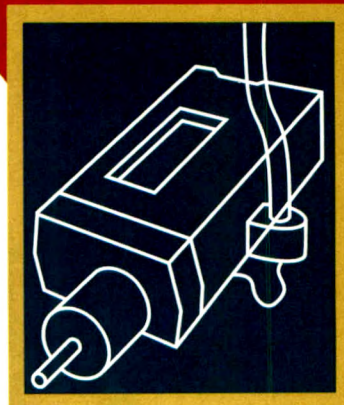
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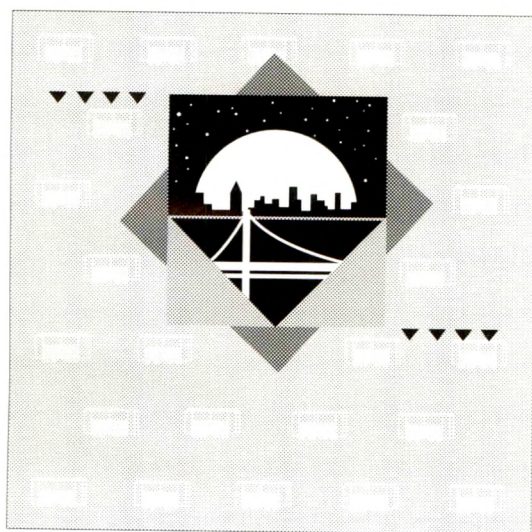
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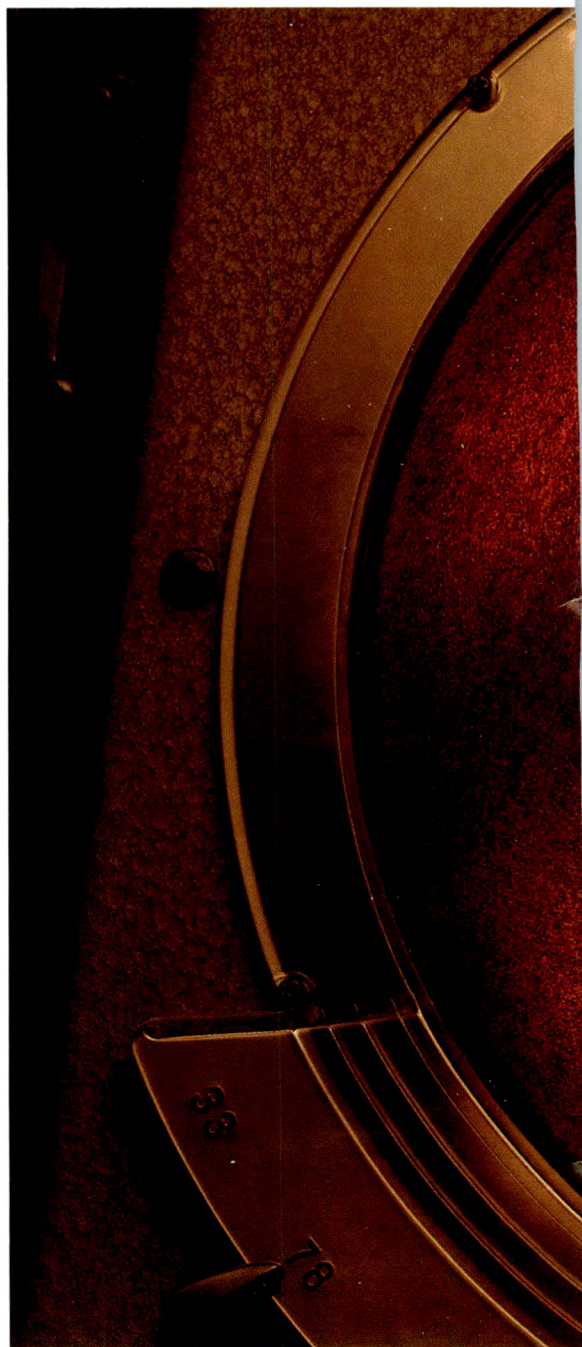
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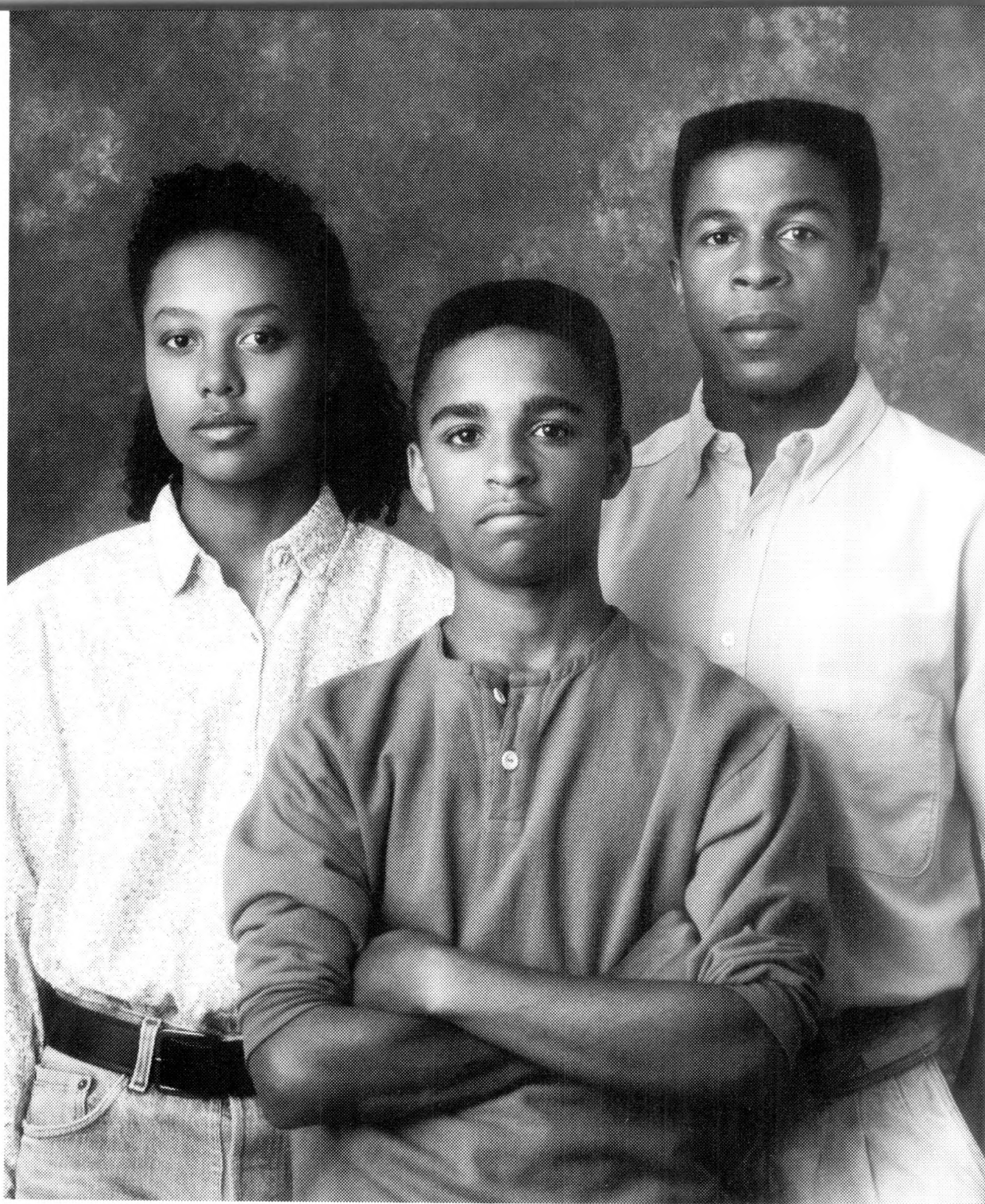
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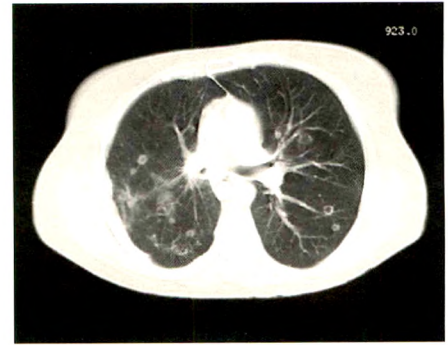
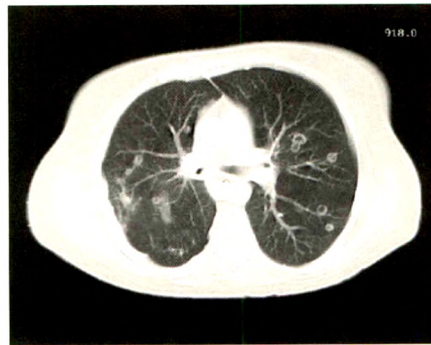
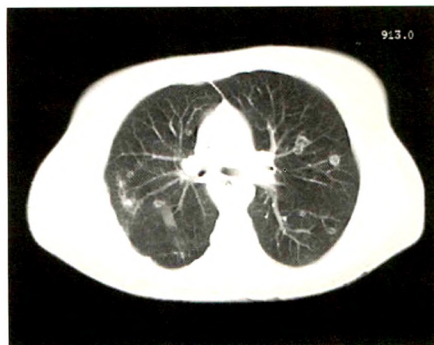
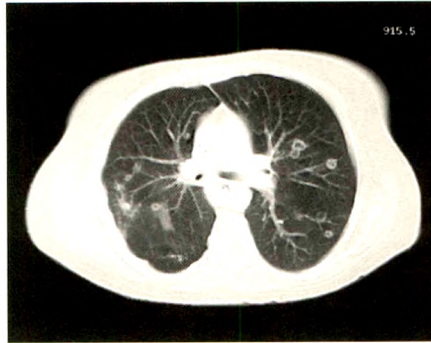
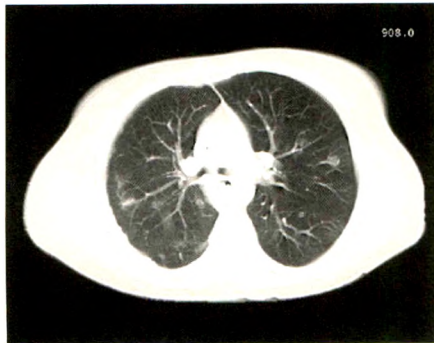
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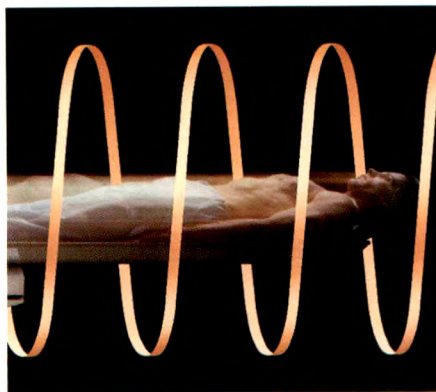
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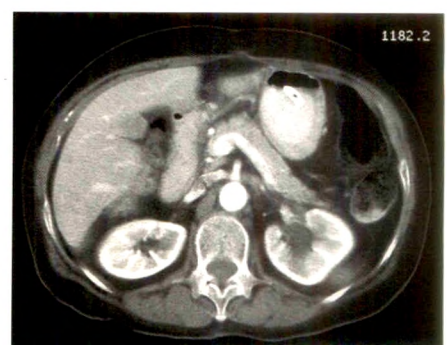
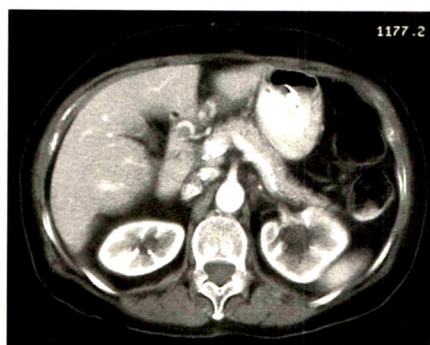
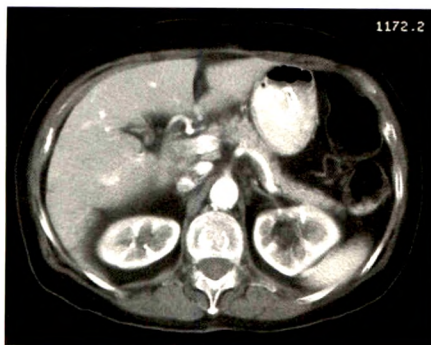
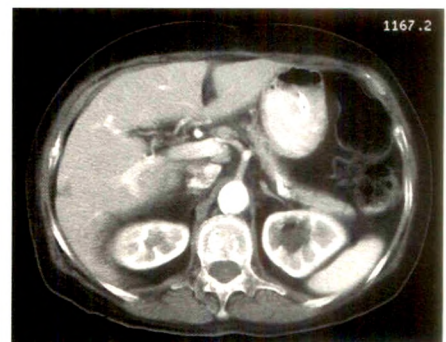
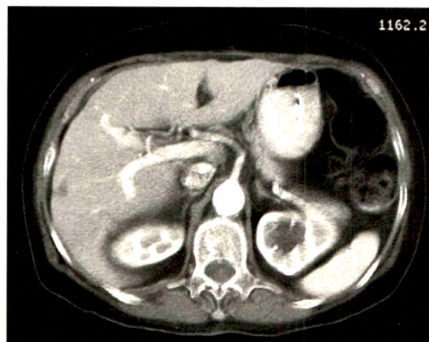
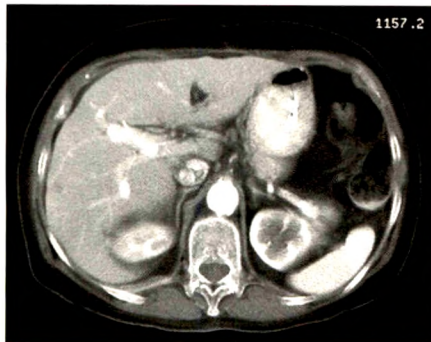
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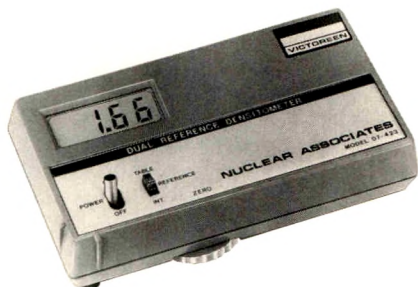
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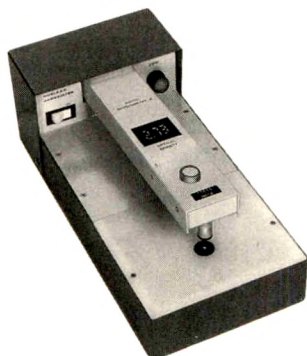
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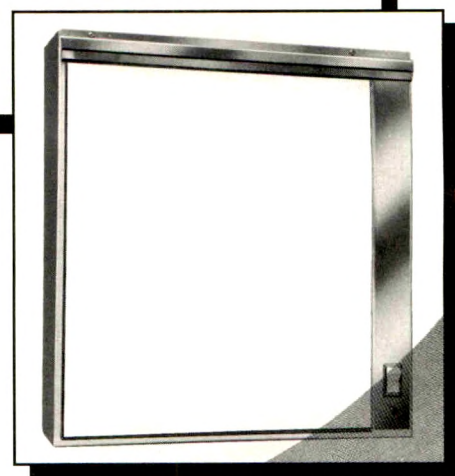
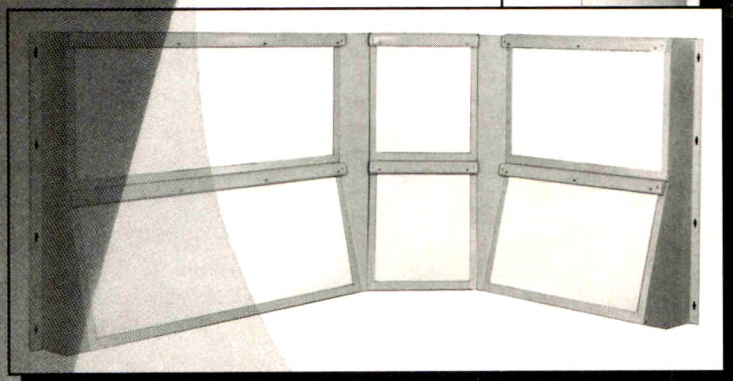
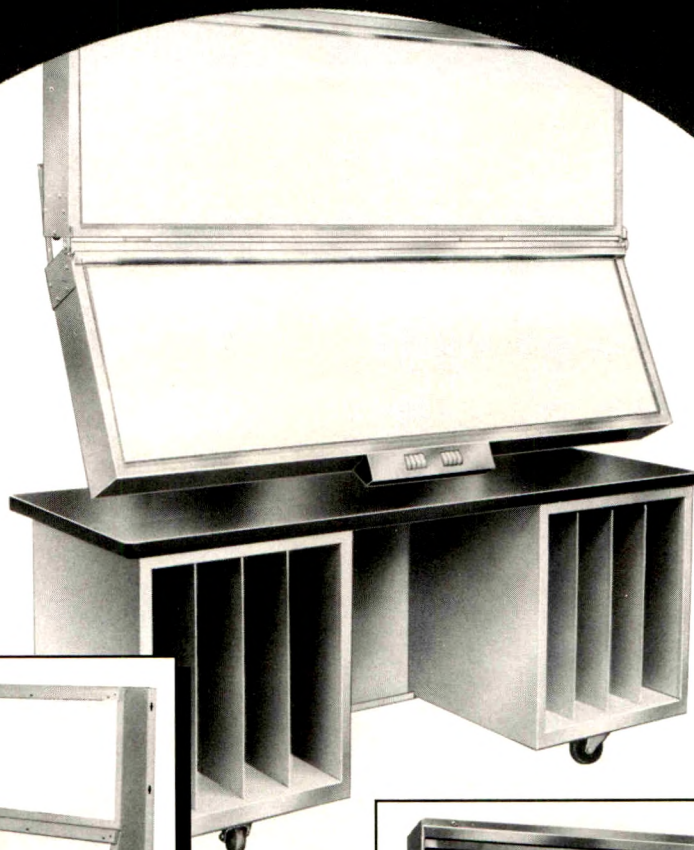


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George W. Holmes Lecture

Deep Venous Thrombosis and Pulmonary Embolism: Correlative Evaluation and Therapeutic Implications

Ernest J. Ferris¹

Deep venous thrombosis and pulmonary embolism are significant causes of morbidity and mortality in the United States; estimates range from 120,000 to 150,000 deaths annually. Although usually symptomatic, deep venous thrombosis can be clinically occult, in part due to incomplete obstruction or in part related to duplication, triplication, and fenestration anomalies, primarily of the superficial femoral or popliteal vein. Additionally, pulmonary emboli caused by deep venous thrombosis may be clinically silent. Because of therapeutic implications, especially indications for insertion of inferior vena caval filters, comprehensive assessments of both the disease process (i.e., deep venous thrombosis) and the complication (i.e., pulmonary emboli) are important. Thus, when a pulmonary embolus is the presenting process, correlative assessment of deep venous thrombosis, even in the absence of symptoms or signs in the lower extremity, may be of therapeutic significance. Conversely, when deep venous thrombosis of the lower extremities involving the popliteal or superficial femoral vein is the presenting process, correlative assessment of the pulmonary circulation, even when no pulmonary symptoms or signs are present, may be of therapeutic significance. Relative to the diagnosis of pulmonary embolism, the roles of assays of D-dimer, ventilation-perfusion lung scans, and segmental occlusion studies of the pulmonary circulation are discussed. Finally, the indications for insertion of inferior vena caval filters above the renal veins are presented and examples are shown.

It is with great pleasure that I accepted the invitation to give the 1992 Holmes Lecture. I have been gone from Boston for 15 years, but have never forgotten my deep association

with the radiology community in New England and with the New England Roentgen Ray Society.

George Winslow Holmes was born December 21, 1876, in Waldo, ME. After his medical training at Tufts Medical School, his internship in medicine at the Boston City Hospital, and his residency in medicine at the Long Island Hospital, he became assistant skiagrapher at the Massachusetts General Hospital, under the direction of James Dodd, from 1910 to 1911. Dr. Holmes established the first radiology residency training program in the United States at the Massachusetts General Hospital in 1915. By 1917, Dr. Holmes was roentgenologist in chief at the Massachusetts General Hospital. In 1931 he became clinical professor of radiology at Harvard Medical School. He was president of the New England Roentgen Ray Society from 1921 to 1922 and gave the first Holmes Lecture of the New England Roentgen Ray Society in 1945. Author of two textbooks and more than 60 articles in the radiologic literature, Dr. Holmes was in great demand as a lecturer and teacher. He delivered the Carmen Lecture of the Radiological Society of North America and received its gold medal in 1937. He also gave the Caldwell Lecture of the American Roentgen Ray Society in 1940. He died March 18, 1959, in Belfast, ME.

I have chosen the topic of deep venous thrombosis and pulmonary embolism, correlative evaluation and therapeutic implications, as the subject of my lecture. My interest in this area has its roots in my early experience at Boston City Hospital and Boston University Medical Center. In the past 15 years, it has been my good fortune to expand and update

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my thinking on this topic at the University of Arkansas for Medical Sciences.

The true prevalence of deep venous thrombosis is not known. It has been estimated, however, that between 120,000 and 150,000 people die each year in the United States of acute pulmonary thromboembolism, and that probably between 750,000 and 900,000 patients have significant severe, usually symptomatic, major pulmonary embolism annually in this country [1].

In order to assess the disease process (i.e., deep venous thrombosis) and its complication (i.e., pulmonary embolism), a structured approach is vital. In this regard, it must be recognized that the clinical manifestations are varied, and hence the use of noninvasive and invasive testing also will vary. Furthermore, dual assessment, first of the process causing the clinical signs and symptoms and then of any other component, be it deep venous thrombosis or pulmonary embolism, may be important with respect to therapeutic implications. I use the term correlative evaluation when deep venous thrombosis is assessed in a patient who has no marked signs or symptoms in the leg but does have major signs and symptoms in the chest. Conversely, correlative evaluation of the pulmonary circulation may be indicated, even though the patient has no pulmonary signs or symptoms, when certain deep venous thrombotic processes occur in the lower extremities.

Peripheral Venous Thrombosis: Diagnostic Evaluation, Significance of Location, and Correlative Lung Scanning

Peripheral venous thrombosis was studied in detail as early as 1860 by Virchow [2]. He recognized that many factors were involved, including venous and endothelial damage, venous stasis, and hypercoagulability of blood. In most patients in whom deep venous thrombosis develops, the thrombus forms initially in the calf veins [3, 4]. This is true with the average patient, but in a smaller group of patients who undergo hip surgery, deep venous thrombosis tends to develop initially in the iliofemoral system, rather than in the calf [5].

Because of the increased use of catheters that are inserted into the upper extremity for long periods, particularly for chemotherapy or pain relief, deep venous thrombosis in the upper extremity is becoming commonplace. In a recent review, Monreal et al. [6] found that six of 30 patients with upper extremity thrombosis (20 catheter related) had evidence of abnormal perfusion on radionuclide lung scans, although the probability of having pulmonary emboli was high in only four of them. Several others [7-10] have found similar relationships between pulmonary embolism and upper extremity deep venous thrombosis. Figure 1 shows an intravascular sonogram of the right innominate vein in a 65-year-old man with symptomatic pulmonary emboli as determined by a radionuclide lung scan (high probability according to the criteria of Biello et al. [11]). Duplex sonography showed no obvious deep venous thrombosis involving either lower extremity, and bilateral lower extremity phlebograms of the calf veins showed no thrombosis. Intravascular sonography of the

right innominate vein showed a large filling defect (Fig. 1A). Findings on venography (Fig. 1B) confirmed the presence of a thrombus. This thrombus might have been overlooked if intravascular sonography had not been used. The patient had had an indwelling catheter inserted by way of the right subclavian vein, and intravascular sonography was used to look for a thrombus (i.e., the source of pulmonary emboli). He had no previous or current signs or symptoms suggesting venous thrombi in the innominate vein. How is this related to pulmonary emboli? The association is so close between venous thrombosis, detachment, and embolization that it is likely that many patients of this type will have pulmonary emboli. If for some reason anticoagulation is contraindicated, then the problem is placement of a filter in the superior vena cava vs the standard position, the infrarenal portion of the inferior vena cava (Figs. 1C and 1D). In our search of the literature, we were able to find only one similar situation in which a filter was placed in the superior vena cava [12].

The diagnosis of deep venous thrombosis is clinically difficult. When signs and symptoms first suggest that the patient might have deep venous thrombosis, diagnosis based on clinical findings is wrong approximately half the time. Furthermore, deep venous thrombosis is asymptomatic in many patients. In one study, in which venography of the lower extremities was performed in patients who had no symptoms or signs of deep venous thrombosis, but who had symptomatic pulmonary emboli, the prevalence of deep venous thrombosis was 30% [5]. Deep venous thrombosis can be asymptomatic for the following reasons [13]: (1) The thrombus may incompletely block the superficial femoral vein or popliteal vein. As flow is not markedly diminished, collateral circulation or stasis with edema below the thrombus does not occur. (2) In many anomalies, duplication (20%), fenestration (8%), or triplication (2%) of the superficial femoral vein or the popliteal vein (5%) occurs [5] (Fig. 2). When that happens, thrombosis of one of the duplicated veins may be asymptomatic because of patency of the parallel duplicated vein, which allows continued venous return without physical findings of obstruction. Figures 3-5 show venous obstruction with and without symptoms. Furthermore, because of the deep collateral circulation, no external manifestation of obstruction occurs. Yet these patients have a high risk of pulmonary thromboembolic disease, particularly if they are not treated [5].

In general, deep venous thrombosis of the calf propagates to the popliteal or superficial femoral venous system in about 20% of patients [14]. It is important to recognize the significance of popliteal venous and superficial femoral venous occlusive disease. Fewer than 10% of untreated patients with calf thrombosis have embolization of thrombus to the lung, whereas embolization occurs in approximately 50% in untreated patients with superficial femoral or iliac venous thrombosis. Furthermore, the hemodynamic changes in the pulmonary circulation would logically tend to be greater when the venous thrombus originates from a large vein such as the superficial femoral vein or the iliac vein.

Just who should be tested for deep venous thrombosis? Obviously, anyone with swelling, pain, and tenderness of the extremity may have venous thrombi in the deep veins of the

Fig. 1.—Thrombus in innominate vein of a 65-year-old man who had an indwelling catheter inserted via right subclavian vein a few months earlier.

A, Intravascular sonogram of right innominate vein shows thrombus (arrows).

B, Venogram of right innominate vein shows thrombus (arrows). This confirms findings seen on intravascular sonogram.

C and D, Frontal (C) and lateral (D) radiographs show a titanium Greenfield filter (arrows) in superior vena cava that was inserted percutaneously via right femoral vein.

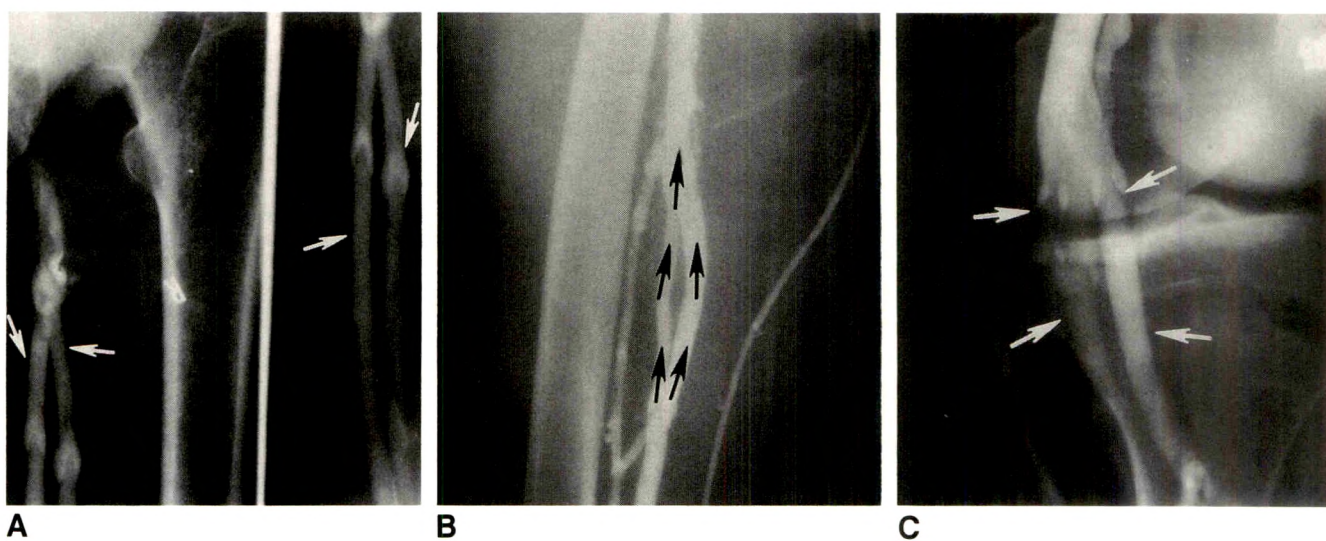
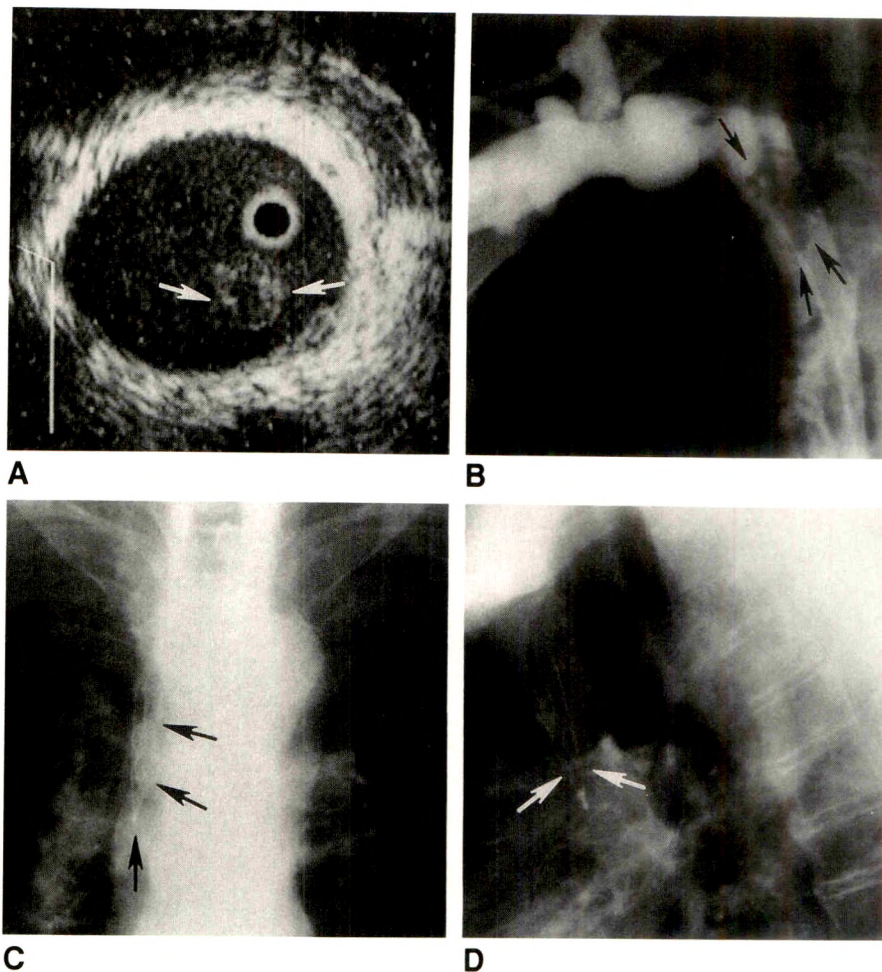


Fig. 2.—Venous anomalies of leg.

A–C, Venograms show duplication of superficial femoral vein (arrows, A); partial duplication or "splitting" of femoral vein with two limbs (arrows, B), creating a fenestrated or windowlike appearance between limbs; and partial duplication of popliteal vein (arrows, C).

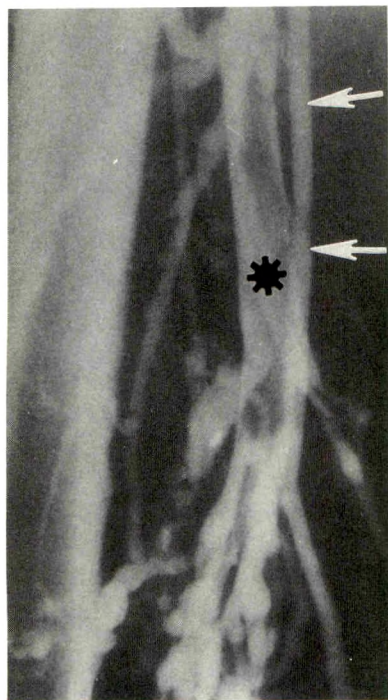


Fig. 3.—Duplication of right superficial femoral vein with thrombus in patient with no symptoms or signs of venous disease. Venogram was obtained to search for a source of pulmonary emboli. Only one limb (asterisk) of duplicated superficial femoral vein has thrombus. Other limb (arrows) is patent and serves as "internal collateral."

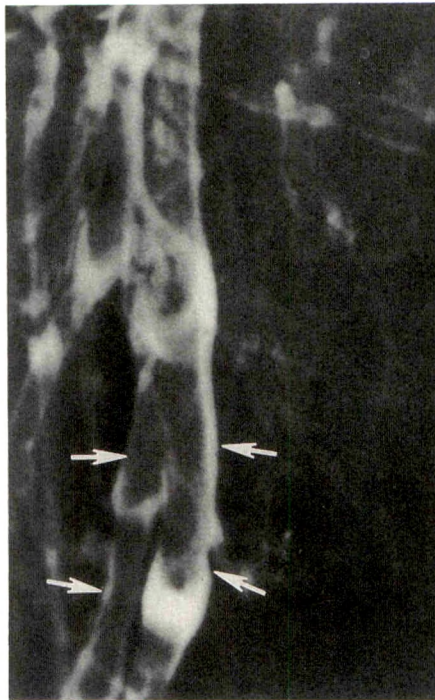


Fig. 4.—Duplication of right superficial femoral vein with thrombi in a patient with findings of edema. Venogram shows thrombi (arrows) in both duplicated segments in midthigh area.

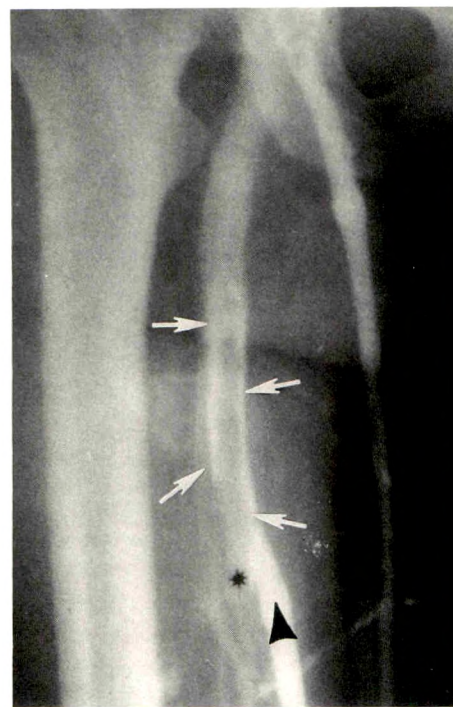


Fig. 5.—Duplication of right superficial vein with thrombus in a patient with known pulmonary emboli, but no signs or symptoms in leg. Venogram shows thrombus (arrows) originating at level of asterisk and extending upward to incompletely obstruct superficial femoral vein. A second patent vein of a fenestrated superficial femoral vein (arrowhead) is present. Incomplete obstruction of superficial femoral vein and presence of thrombus in only one fenestrated vein probably accounted for absence of signs and symptoms in leg.

lower extremity. Predisposing factors include varicose veins; abdominal surgery; hip surgery; neoplasia; pregnancy; stasis caused by lack of activity; and hypercoagulable states such as polycythemia, dysproteinemia, and abnormal clotting factors (associated with various malignant tumors).

At the University of Arkansas, the diagnosis of deep venous thrombosis is generally approached in one of three distinct ways: (1) If the patient has clinical signs and symptoms that suggest deep venous thrombosis, duplex sonography is performed. A study [15] that compared venography and duplex sonography of the lower extremities has shown that this is a highly accurate method of detecting deep venous thrombosis from the popliteal vein and cephalad (more than 98% correlation). (2) In those patients in whom deep venous thrombosis is likely, particularly those who are inactive or have had surgery, duplex sonography screening is performed at the bedside. (3) In those patients who do not have signs and symptoms in the leg and in whom pulmonary embolism is unlikely, pulmonary scintigraphy after injection of radionuclide via the dorsal vein of both feet is used as a screening mechanism to detect occult deep venous thrombosis involving the superficial femoral or iliac veins. In a study [5] of 300 venograms of the lower extremities followed by radionuclide venograms, findings on the radionuclide venogram were abnormal in 75% of those patients with deep venous thrombosis

involving the superficial femoral, popliteal, or iliac veins. Hence, radionuclide venography can be used for screening. If findings on the radionuclide venogram are abnormal, then duplex sonography will be performed. If findings on the radionuclide venogram are normal, however, several alternatives are possible. If findings on the ventilation-perfusion lung scan indicate a high or an indeterminate probability of pulmonary emboli, then duplex sonography is still performed. On the other hand, if findings on the ventilation-perfusion lung scan are normal or indicate a low probability of pulmonary emboli and those on the radionuclide venogram are normal, then the duplex scan is not obtained. Our experience shows the diagnostic yield from such studies is negligible. Although duplex sonography of the extremities could be done in these patients, our impression is that the inherent cost, along with a low yield, does not justify its routine use.

Pulmonary Thromboembolism: Method of Lung Scanning, Correlation with Lower Extremity Venous Disease, Approaches to Angiographic Evaluation of the Pulmonary Circulation, and Interruption of the Inferior Vena Cava

The routine evaluation of pulmonary thromboembolism includes analysis of blood gases, chest radiography, and ven-

tilation-perfusion scanning. As mentioned previously, ventilation-perfusion scanning can be performed by way of the dorsal veins of both feet in patients with no signs or findings in the leg, unless duplex sonography already has shown that deep venous thrombosis is present.

The criteria of Biello et al. [11] are used to determine whether the ventilation-perfusion scans indicate high, indeterminate, or low probability of pulmonary emboli. Unfortunately, patients whose ventilation-perfusion scans indicate an indeterminate probability of pulmonary emboli need further examination (i.e., pulmonary arteriography). My colleagues and I have not been comfortable concluding that lung scans that indicate low probability mean that the patient has no significant pulmonary emboli. On the other hand, this is the approach generally advocated, and thus we use it with the following modifications. If the lower extremities appear normal, either according to results of duplex sonography or radionuclide venography, and the clinical findings and results on ventilation-perfusion scans indicate a low probability for pulmonary embolism, then we are reasonably confident in eliminating pulmonary embolism as a diagnosis. If any of these factors are debatable, then even the patient whose ventilation-perfusion scan indicates a low probability of pulmonary embolism should have pulmonary arteriography. In these instances, the ventilation-perfusion scan might appear to be relatively superfluous. Yet the scan is important because the area of abnormality seen on the lung scan is the area that is primarily examined by arteriography. We know from past experience [16] that areas of perfectly normal perfusion do not have pulmonary emboli, and hence these areas are not evaluated by angiography.

In a study of patients who had pulmonary emboli [5], as shown by pulmonary arteriography, we assessed the prevalence of asymptomatic deep venous thrombosis involving the popliteal or the superficial femoral vein (where the prevalence of embolization is high). In a series of 78 patients who had evidence of pulmonary emboli on pulmonary arteriograms but no findings in the legs, we found by either radionuclide venography or venography that 24 patients (31%) had asymptomatic deep venous thrombosis of the superficial femoral or popliteal vein.

Conversely, in those patients who have deep venous thrombosis with involvement of the superficial femoral vein or iliac system, the prevalence of asymptomatic pulmonary embolism as judged by a routine baseline ventilation-perfusion scan was significant. In 62 patients with deep venous thrombosis (mostly popliteal or superficial femoral), 24 (39%) had ventilation-perfusion scans that indicated a high or indeterminate probability of pulmonary embolism.

Occlusion Pulmonary Arteriography

Although the standard approach for pulmonary arteriography is insertion of a catheter into the left or right pulmonary artery and visualization with different projections, we have sometimes modified this approach. In patients with marked arrhythmias, a Berman flow-directed balloon catheter (Arrow, Inc., Reading, PA) can be used. Because of this approach, the ventricular septum usually is not irritated. This may dimin-

ish cardiac disturbances. In some patients, with the assistance of the ventilation-perfusion scan as a guide, areas just proximal to the abnormal segment can be selectively studied by using balloon occlusion angiography. This type of angiography can be performed with flow-directed balloon catheters such as the modified Swan-Ganz catheter (Arrow, Inc.). By altering the diameter of the lumen of the modified Swan-Ganz catheter, a 0.035-in. (0.089-cm) guidewire and a modified Seldinger technique can be used. The catheters are inserted through a sheath. They can be easily directed and partially controlled via either the gas-filled balloon or various tip-deflecting guidewires [17, 18]. The balloon of the modified Swan-Ganz catheter can be expanded to approximately 12 mm, which is sufficient to obturate and study several segments, including the segments that appear abnormal on ventilation-perfusion scans. Figure 6 shows balloon occlusion arteriograms of normal and abnormal pulmonary circulation. In this way, not only is less contrast material used, but also the hemodynamic effect, particularly in those patients who have some increase in pulmonary pressure, is considerably less. In a series of 38 patients who had both pulmonary angiography and balloon occlusion arteriography, four cases of pulmonary emboli in 38 patients would have been missed without the balloon occlusion studies [16].

Pulmonary Emboli Intervention

Although the standard therapy for pulmonary emboli and deep venous thrombosis is anticoagulant therapy, in some patients, administration of anticoagulants is not safe or is not effective. In those situations, usually an inferior vena caval filter is introduced.

In 1972, Lazar Greenfield introduced the Kimray-Greenfield filter (Boston Scientific Co., Watertown, MA), which now is the standard for comparison. This filter, initially inserted by using a surgical cutdown and a 24-French carrier, has also been introduced percutaneously through the jugular or femoral vein. The patency rate is high, about 95%, and the prevalence of pulmonary thromboembolism is low, 1–3% [19]. In the past few years, various percutaneous filters have been introduced; currently, five filters are approved by the Food and Drug Administration: the Simon nitinol filter (Nitinol Medical Technologies Group, Woburn, MA), the titanium Greenfield modified hook filter (Boston Scientific Co.), the Bird's Nest filter (Cook, Inc., Bloomington, IN), the Vena Tech filter (Braun Vena Tech, Evanston, IL), and the standard Greenfield filter (Boston Scientific Co.). The carriers used vary from 8 to 14 French (except the Greenfield 24-French carrier). Again, the route of insertion is the internal or external jugular vein or the femoral vein [20]. The Simon nitinol filter has been modified so that it can be introduced from an arm vein also.

In general, the filter location is infrarenal. In some circumstances, however, the filter is inserted above the renal vein [12, 21, 22]. In young women who expect to become pregnant at some time, it may be advantageous to insert the filter between the renal vein and the right atrium (i.e., the intrahepatic portion of the inferior vena cava). In this way, the filter will not be compressed by an enlarged uterus. Furthermore, the right ovarian vein drains too far cephalad to exclude its

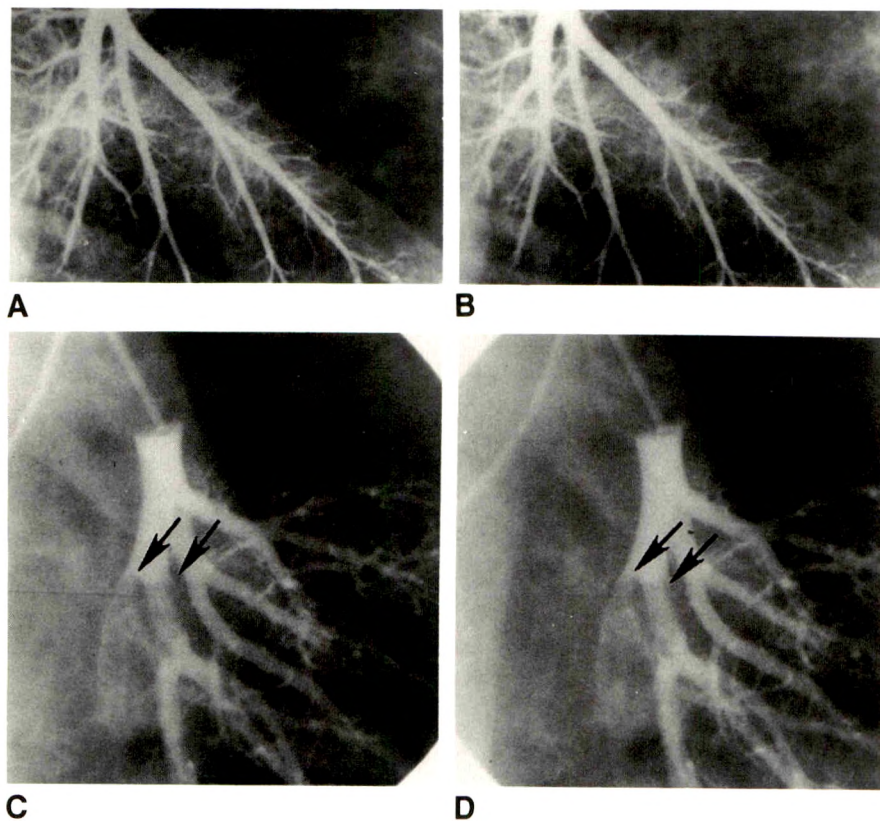


Fig. 6.—Balloon occlusion arteriography with modified Swan-Ganz catheter to show circulation in pulmonary arteries in left lower lobe.

A and B, Arteriograms show excellent detail of normal pulmonary circulation.

C and D, Cineangiograms show a small "saddle embolus" (arrows) in posterior and lateral segments.

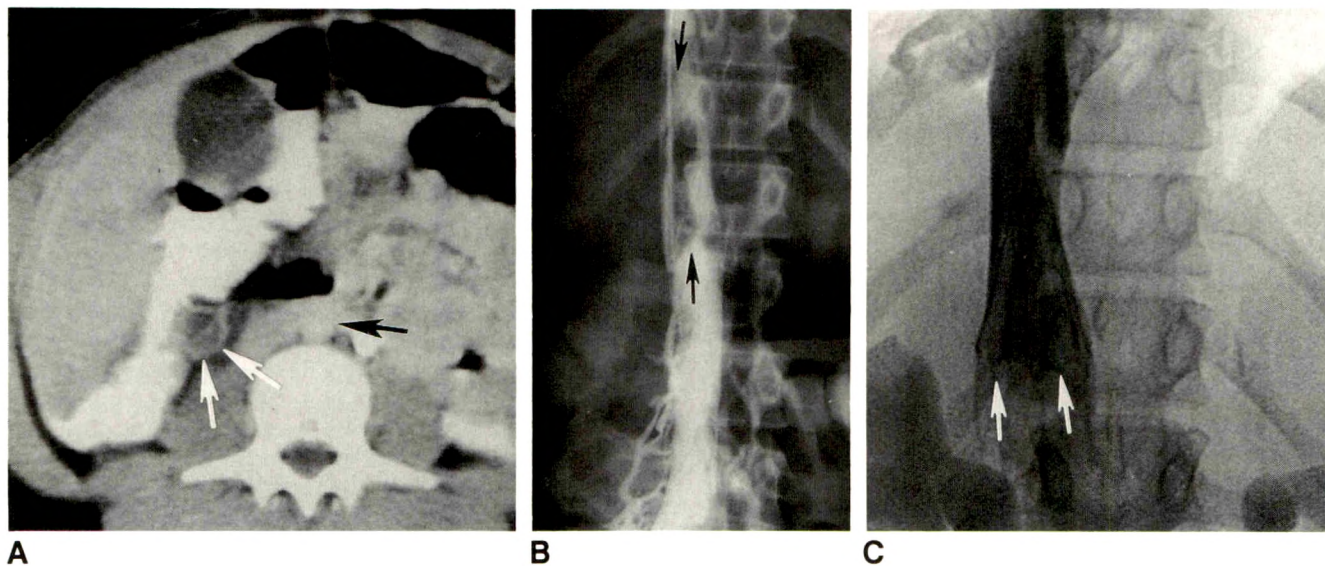


Fig. 7.—Right ovarian vein syndrome in a young woman who had abdominal pain and fever for several weeks postpartum.

A, CT scan after contrast administration shows thrombus in right ovarian vein (white arrows). Caval enhancing wall "rims" thrombus. Black arrow denotes aorta.

B, Anteroposterior inferior venacavogram shows a large thrombus (arrows) that has propagated from right ovarian vein into upper inferior vena cava.

C, Angiogram shows titanium Greenfield filter placed in hepatic portion of inferior vena cava above renal veins in this young woman who had massive pulmonary emboli. Arrows show filter base. Note filter carrier, which was percutaneously inserted from right internal jugular vein.

circulation by the placement of an infrarenal filter, and the left normally drains into the left renal vein. One can appreciate the fact that the standard infrarenal filter position would not prevent emboli from the left ovarian vein from entering the

pulmonary circulation. The pelvic area is a frequent site of thrombophlebitis and pulmonary embolism in young women [23]; hence, an infrarenal filter may not be particularly useful in this type of patient. Figure 7 illustrates an example of

suprarenal filter placement. In those patients who have renal vein thrombosis or who already have a filter in place below the level of the renal veins that is ineffective, a filter might be inserted in the intrahepatic segment of the inferior vena cava.

In a patient who has had a second major bout of pulmonary emboli, filter insertion is a customary consideration. How to determine just when a pulmonary embolism is the second episode is not always easy. Thus, it is standard practice at my institution to obtain a baseline ventilation-perfusion scan in any patient who has deep venous thrombosis involving the superficial femoral, popliteal, or iliac veins. The reasons for this are obvious. If signs and symptoms develop in the chest after several days of anticoagulant therapy, another scan can be obtained and comparative analysis done. If no obvious change has occurred, or if the embolus has moved from a lobe area to subsegmental areas in the normal anatomic distribution, it is likely that the patient has not had recurrent pulmonary embolism, but that the initial pulmonary embolus is now clinically manifest. Conversely, if the second ventilation-perfusion lung scan shows that different areas are involved, the most likely situation is failure of anticoagulation and recurrent pulmonary emboli, and a filter might be indicated. Without that baseline ventilation-perfusion scan, a wise decision on placement of a filter would be difficult.

New Techniques

CT and MR imaging have been applied to the diagnosis of pulmonary embolism and deep venous thrombosis [24]. These techniques, however, are still investigational to some degree. One aspect that might be helpful in the diagnosis is to assay D-dimer, a breakdown product of fibrin that is currently being studied intensively. A normal D-dimer level precludes a pulmonary embolus. However, because elevated levels of D-dimers are common after surgery, D-dimer levels are unreliable indicators of pulmonary embolism in postsurgical patients [25].

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Book Review

Diagnostic Imaging of the Lung. Edited by Charles E. Putman. (No. 46 in the series Lung Biology in Health and Disease.) New York: Marcel Dekker, 769 pp., 1990. \$165

To quote from Dr. Putnam's preface, he was "extremely fortunate to have identified and persuaded a very talented group of clinical investigators to pursue each of the selected topics." Chapters are "An Overview of Thoracic Imaging," "Imaging of the Airways," "Diagnostic Imaging in Pulmonary Vascular Disease," "Primary and Metastatic Malignancy," "Pulmonary Edema—Cardiac and Noncardiac," "Acute Diffuse Lung Disease," "Chronic Diffuse Lung Disease," "Congenital and Acquired Focal Lung Disease," "Interventional Procedures of the Chest," and "Future Goals and Objectives for Thoracic Imaging."

The paper and printing are of excellent quality. The radiographs, CT scans, MR images, and scintigrams number about 350 and are quite large and detailed. The descriptions of diseases are good, and the pathophysiology of the processes is explained well and concisely.

This is one volume of a multivolume series entitled Lung Biology and Disease, so it must appeal to those in radiology, chest medicine, intensive care medicine, and thoracic surgery and to those who do not deal primarily with respiratory or pulmonary diseases. As such, the material is timely and extremely valuable. Because the book is part of a multivolume series, however, the common format that the editor must use is the limiting factor in the attractiveness of this text.

Although the book is 769 pages long, 25 of these are devoted to a rather skewed subject index. Twenty-six separate lines are devoted to Swyer-James (Macleod) syndrome, whereas no category is listed under pneumonia. Correspondingly, the entry on perception and analysis takes up 186 separate lines, whereas entries on vascular perfusion scanning and pulmonary emboli take up only four lines. The author index extends over 44 pages, referring to the authors in the reference portions of each section of text, but the reference pages for the 10 chapters number an additional 121, so 190 of 769 pages pertain to subjects and authors, and only 579 include text material. Many of these 579 are devoted to radiographs and descriptions of the radiographs. All of this tends to limit the amount of written text, and thus many of the subjects seem to be quite brief.

Further, whereas the usual size of a page in a journal (e.g., *AJR*) is approximately 21 × 28 cm, this volume has small pages of 15 × 23 cm. In addition, the printing is quite large, and each page has no more than 42 lines of text. This would not seriously hamper the text if the book did not have so much repetition with regard to the references. For example, on page 236, when discussing the evaluation of adrenal metastases, the author states, "there have been several investigations regarding the use of MRI in distinguishing adrenal adenomas from adrenal metastases (Baker et al., 1987; Chang et al., 1987; Chezmar et al., 1988; Francis et al., 1988a, 1988b; Glazer et al., 1986; Reinig et al., 1986a, 1986b)." Six lines farther on, when the author discusses that the metastases were typically more intense than adenomas at these sequences, the citations are "(Chang et al., 1987; Glazer et al., 1986a; Reinig et al., 1986a, 1986b)" and then two lines later, "(Glazer et al., 1986a; Reinig et al., 1986a, 1986b)" and again three lines later, "(Glazer et al., 1986a; Reinig et al., 1986a, 1986b)."

In three separate paragraphs Glazer et al. are referred to at least five times, Chang et al. at least seven times, and Reinig et al. at least four. None of the references is given a number, and frequently one author will have seven or eight separate articles cited. Although this is exact, it causes the reader to stumble when two or three or sometimes even four lines of text include nothing but names and years referring to authors whose works are correctly referenced at the end of each chapter and again in the 121 separate pages at the end of the book.

The authors do include Professors Gamsu, Glazer, Godwin, Goodman, Gross, and Milne, among others, and when the limitations of the format of the series are discounted, the subject matter and the descriptions are well worth reading in this volume.

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Review Article

Radiation Effects on the Lung: Clinical Features, Pathology, and Imaging Findings

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We are sometimes actually thrown upon the horns of the dilemma: whether it is better to try to extinguish the disease, or risk extinguishing the patient.

McIntosh and Spitz [1]

Radiation-induced injury to the lungs is well recognized as a potential complication in the treatment of patients with carcinomas of the breast, lung, or esophagus; lymphomas; or other mediastinal neoplasms. Since the initial report by Groover et al. [2] in 1922, the clinical, pathologic, and radiologic aspects of radiation damage to the lungs have been investigated extensively. Several excellent reviews have been published [3–10].

Systematic analysis of the sequence of events in radiation-induced lung injury is a difficult task. Over the past 70 years, clinical reports have encompassed a variety of malignant tumors and radiotherapeutic techniques. Histopathologic study of the human lung has been limited by the sporadic nature in which autopsy material is obtained [7]. Some valuable insight into the earliest pathologic changes has been derived from experimental animal studies. However, such investigation is limited by the inherent problem of extrapolating from data on small mammals to applications in humans [6].

This review summarizes the pertinent clinical, pathologic, and imaging features of radiation-induced lung injury, as these are currently understood. Recurrent concerns over the previous decades are highlighted: (1) How can radiation effects on the lung be detected and distinguished from possible

infection, recurrent or metastatic neoplasm, or drug-induced toxic effects? (2) What is the underlying pathogenesis for the observed changes?

Clinical Features

Two distinct clinical stages, an early transient *radiation pleuropulmonitis* and a later chronic *radiation fibrosis*, were recognized even in the earliest reports [11, 12]. As recommended by Chu et al. [13], the acute syndrome is now referred to as *radiation pneumonitis*. It usually occurs about 4–12 weeks after treatment is completed [3–5, 7, 8, 12]. Signs and symptoms include dyspnea, cough, low-grade fever, and chest discomfort, and these generally subside spontaneously over several weeks. In a few cases, the course may be fulminant; although this is often fatal, resolution may be complete [8, 14]. Commonly, the acute reaction is clinically silent.

Onset of radiation fibrosis may be manifested by gradually increasing dyspnea, persistent dry cough, or signs and symptoms of cor pulmonale. However, this stage is often asymptomatic, recognized only when an abnormality is seen on radiographs or secondary infection, bronchiectasis, or spontaneous pneumothorax develops [9]. Often, clinical or radiologic evidence indicates radiation fibrosis, without any clear antecedent radiation pneumonitis [7, 8, 14].

For treatment of acute radiation pneumonitis, immediate bed rest and use of cough suppressants or salicylates are recommended as palliative measures [5, 7, 8, 11]. Antibiotics

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are of value in treating superimposed infection but should be given only if sputum cultures are positive for a causative organism [5, 7, 8]. The prompt institution of high-dose corticosteroid therapy will often alleviate acute signs and symptoms and help avoid fatality, but inexorable progression to fibrosis may still occur [4, 5, 8]. Once fibrosis is established, corticosteroids are no longer of benefit [5]. Little evidence supports the prophylactic use of either corticosteroids or anticoagulants [4, 5, 7].

Throughout the years, it has been recognized that multiple factors influence the development of radiation reaction within the lungs. The importance of total dose, dose rate, and volume of lung irradiated is undisputed [3, 5, 7, 8]. For unilateral irradiation with fractionated dose schemes, total doses of less than 3000 cGy (1 Gy = 100 rad) are usually well tolerated; radiographic changes are variably present in patients who receive doses between 3000 and 4000 cGy and are almost always seen in patients who receive doses greater than 4000 cGy; reactions tend to be more severe with doses near 5000 cGy [5, 15]. Fractionation of the total dose most likely permits repair of sublethal damage [7]. It is thus expected that small doses administered over a long time would be better tolerated than the same or a larger dose administered over short intervals or at a single time [11, 15, 16].

According to Rubin and Casarett [5], the volume of lung irradiated may be the most important factor. These authors have observed that even large doses are usually well tolerated, despite localized pathologic alterations, if less than 50% of one lung is irradiated. On the other hand, bilateral irradiation, irradiation of the mid and lower lung zones, and use of lateral or oblique multidirectional ports are often associated with serious consequences [5, 17]. In the treatment of breast carcinoma, tangential ports are now used to minimize the volume of lung tissue irradiated. Chu et al. [13] noted that radiation pneumonitis occurred in only 7% of cases when this technique was used, as compared with a reported prevalence of about 60% for direct portal irradiation.

Even under comparable treatment conditions, marked individual variation still occurs with respect to the prevalence, severity, time of onset, and clinical outcome of radiation damage to the lungs. Occasionally, radiation pneumonitis develops in patients who receive less than 500 cGy [18]; other patients may emerge unscathed after heavy irradiation [3]. Even different portions of one lung may respond differently. In a study of 36 dogs, Stetson and Boland [19] found that, for the same dose, a more severe reaction occurred with irradiation to the periphery of the right lower lobe than with irradiation to the right hilum.

A number of sensitizing factors have also been recognized. Previous or concurrent chemotherapy, with agents such as actinomycin D, Adriamycin, bleomycin, and busulfan, is known to predispose patients to the development of radiation pneumonitis [20]. Reduction of the total radiation dose by at least 10–15% has been recommended in this setting [8]. In addition, abrupt withdrawal from corticosteroid treatment may unmask latent radiation injury to the lungs [21]. Previous irradiation of the lungs also lowers the threshold for overt reaction. The literature describes many fatal cases, in which

repeated courses of irradiation had inadvertently been given for presumed malignant disease [1, 8]. The importance of other factors, such as habitus, age, and preexisting pulmonary disease, is more controversial [1, 3, 5, 12, 13, 22].

Pathologic Findings

General agreement exists about the overall sequence of pathologic events that occur after irradiation of the lungs. Ionizing radiation results in the production of free radicals that damage cell membranes and chromosomal DNA, leading to cellular dysfunction and mitotic cell death. An initial latent period reflects the inherent turnover time of the affected alveolar epithelial and endothelial cells [6, 7, 9, 10, 16]. Subsequently, as in any other example of diffuse alveolar damage, a limited and stereotypical response of the lung to injury occurs, manifested by an acute exudative phase, an organizing or proliferative phase, and a chronic fibrotic phase [23]. The first two phases correspond to the clinical and radiologic stage of radiation pneumonitis and the third phase corresponds to the stage of radiation fibrosis [7]. These three phases appear at about 0–2 months, 2–9 months, and more than 9 months after treatment, respectively [7]. However, the terms acute and chronic reflect the pathologic appearance and do not necessarily refer to an absolute time frame [3, 5, 9].

In the acute phase, swelling, vacuolation, and sloughing of both capillary endothelial and alveolar epithelial cells occur [5, 8]. Injury to the microvasculature results in capillary congestion and thrombosis. Protein-rich fluid flows from the capillaries into the interstitium, across a damaged alveolar epithelium, and into the air spaces [8, 10]. Within some alveolar air spaces, hyaline membranes are formed from a combination of desquamated epithelial cells, fibrin-rich exudate, and macrophages [3, 8, 18, 24]. Cells that line the alveoli, particularly type II pneumonocytes, proliferate to replace the sloughed epithelial cells and often have marked cytologic atypia, with enlarged hyperchromatic nuclei and multinucleated forms [8, 16, 23, 24].

Diverging opinions exist on the relative importance of specific cell types and the proposed mechanisms of injury. On the basis of ultrastructural studies with experimental animal models, investigators have variously suggested that the earliest effects of irradiation occur within type I pneumonocytes, type II pneumonocytes, endothelial cells, or all three cell types [9]. Moreover, in contrast with the conventional view that edema arises primarily from injury to the microvasculature, it has been proposed that deficiency of surfactant, resulting from injury to type II pneumonocytes, may play an important role; a decrease in surfactant would lead to alveolar instability and collapse, followed by passage of interstitial fluid into the air spaces [6].

In the intermediate phase, progressive organization of intraalveolar exudate occurs [8, 18, 24]. Atypical cells lining the alveoli remain prominent. Interstitial thickening is due not only to persistent edema but also to an increased number of mononuclear cells and the early deposition of collagen fibrils (Fig. 1). Occasionally, full restoration of normal architecture

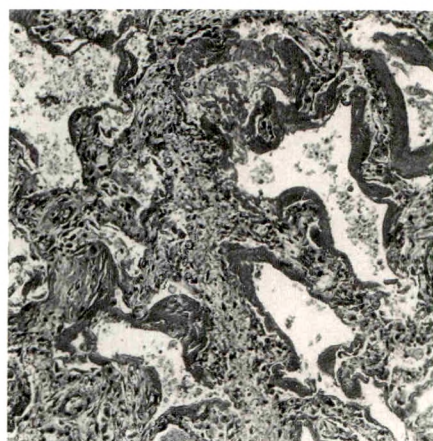
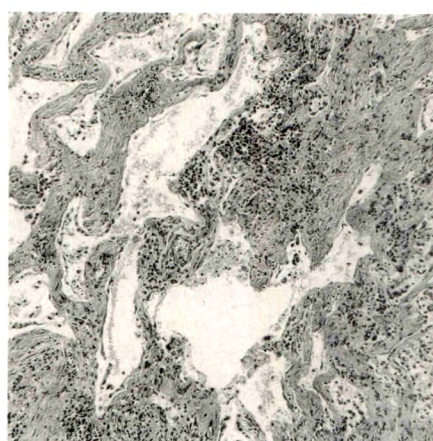
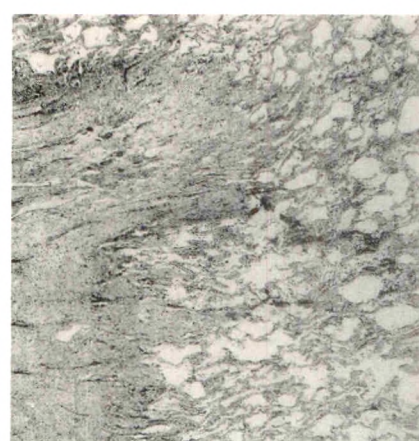


Fig. 1.—54-year-old man in whom acute radiation pneumonitis developed 3 months after initiation of radiation therapy for Hodgkin's disease (4000 cGy to the mantle, over 5 weeks) and who died 37 days later. Photomicrograph shows thickening of alveolar septa by edema, fibrous tissue, and a few inflammatory cells; hyaline membranes line most, but not all, alveolar air spaces. (H and E, original magnification $\times 90$) (Reprinted with permission from Fajardo [24].)



A



B

Fig. 2.—63-year-old man 6 years after total radiation dose of 4600 cGy.
A, Photomicrograph shows marked fibrous thickening of interalveolar septa. (H and E, original magnification $\times 90$)
B, Peripheral area of specimen reveals obliteration of septa and alveoli by dense fibrosis on left. Edge of fibrous scar corresponds roughly to edge of radiation field. (H and E, original magnification $\times 25$)
(Reprinted with permission from Fajardo [24].)

and function occurs. However, resorption of exudate may be impaired if obstruction or perhaps even direct radiation damage to lymphatics is present [8]. Resolution is also less likely if the early effects are severe or of long duration [5, 8].

If complete resolution does not occur, chronic fibrosis gradually evolves. Hyaline membranes and atypical cells lining the alveoli are no longer present. The interstitium is no longer thickened by edema and inflammatory cells, but rather by a marked increase in the deposition of fibrous tissue [8, 18, 24] (Fig. 2). As a result, alveolar air spaces are collapsed and almost completely obliterated.

Other targets of injury, in addition to the alveolocapillary membrane, include arteries, bronchi, and pleura. Within the intima and media of arterioles and even larger arteries, edema occurs; this is followed by proliferative changes and eventual hyalinization. Such sclerosis may cause ischemia and, secondarily, even further fibrosis [6, 8]. Several authors [6, 8, 16, 24] have suggested that alterations within airways are due to superimposed bacterial infection, because the bronchial and bronchiolar epithelium is relatively radioresistant. Nevertheless, focal necrosis of bronchial mucosa, increased mucus production, shedding of ciliated epithelial cells, and eventual squamous metaplasia have been attributed to a direct radiation effect [7, 16]. Similarly, although the pleura is thought to be infrequently affected by irradiation, vacuolation and sloughing of serosal cells or disruption of underlying elastic tissue may occur [16]. Pleural effusions may appear acutely, later followed by development of pleural fibrosis and adhesions.

None of these pathologic changes is specific for a radiation effect. Certain findings, such as hyaline membranes, marked cytologic atypia within pneumonocytes, foamy macrophages within the intima or media of vessels, and vascular sclerosis,

are suggestive of radiation-induced injury [3, 5, 18, 23]. However, a combination of these findings or confinement of changes to the radiation port (Fig. 2B) is considered even more diagnostic of a radiation effect [3, 5, 7].

Radiologic Findings

Chest Radiography

Chest radiography has long been the mainstay for detecting radiation-induced changes, providing some *in vivo* insight into the sequence of pathologic alterations. Clinical signs and symptoms are frequently absent or minimal in the acute or chronic stage [15]. Serial pulmonary function testing may reveal impairment of gas exchange, a reduction in lung volumes, a decrease in compliance, or a decrease in maximum breathing capacity [4, 5, 7, 10]. Focal abnormalities, however, may not be reflected in alterations of overall pulmonary function. In patients with bronchogenic carcinoma, pulmonary function may even improve after radiation treatment of the primary neoplasm [6].

The earliest radiographic changes in radiation pneumonitis may be subtle, with slight indistinctness around vessels or faint hazy opacity, or may be more marked, with patchy or homogeneous air-space consolidation [7, 8, 10, 15, 25] (Figs. 3A and 3B). Initial radiolucency has been described [3], but this is not a common finding [4, 7, 10]. Occasionally, a pleural effusion develops on the irradiated side, coincidentally with the acute pneumonitis [26]. According to Libshitz and Southard [15], radiographic changes of radiation pneumonitis usually appear about 8 weeks after treatment with 4000 cGy, delivered over a period of 4 weeks, and about 1 week earlier for every 1000-cGy increment over 4000 cGy.

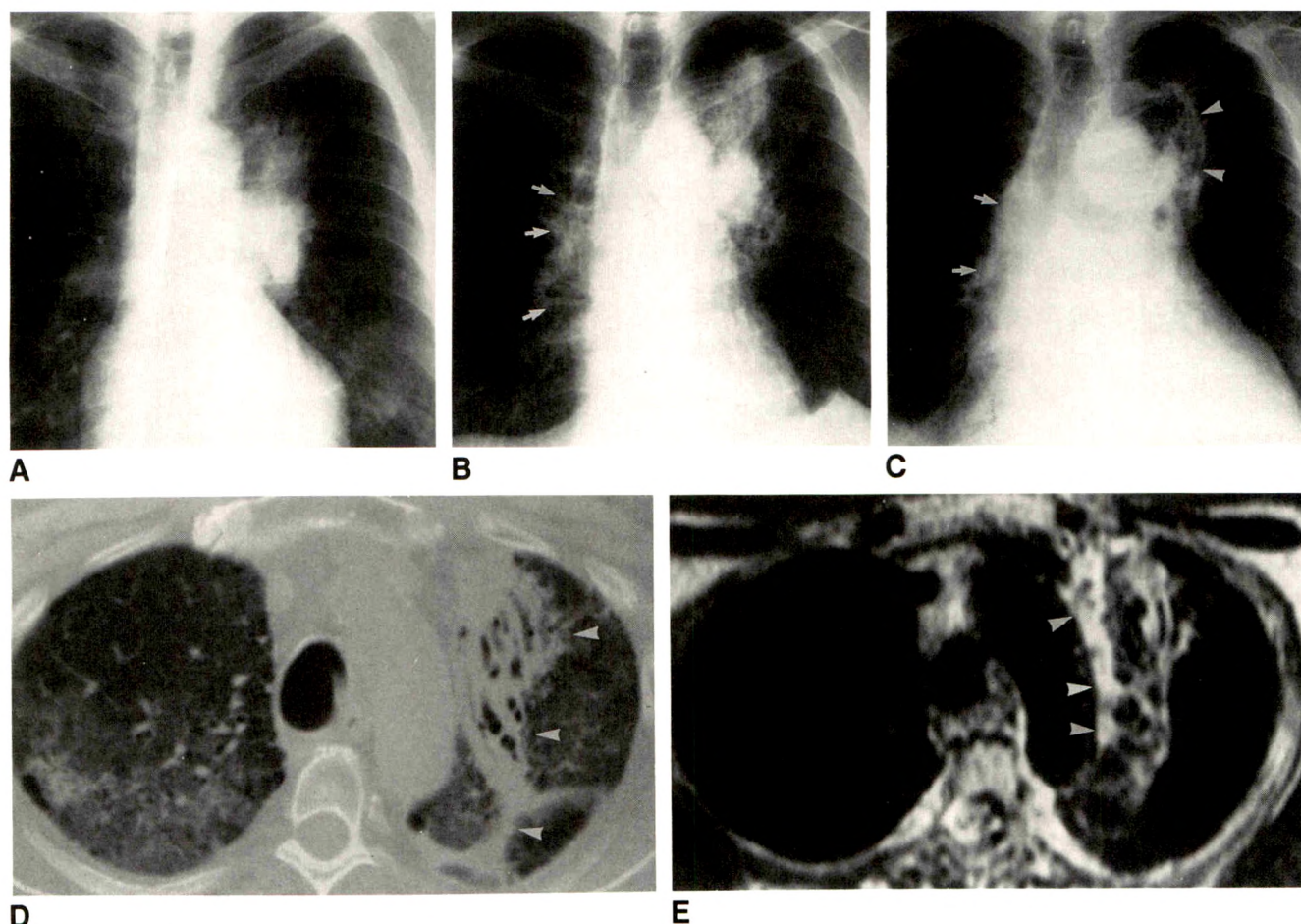


Fig. 3.—71-year-old man with unresectable non-small-cell lung cancer.

A, Chest radiograph obtained before radiation treatment shows mass in left upper lung involving left hilum.

B, Radiograph obtained 3 weeks after treatment was completed (total dose of 6120 cGy) shows confluent parenchymal infiltration extending beyond tumor mass and new haziness around vessels at right hilum (arrows).

C, Follow-up radiograph obtained 1 year after treatment was completed shows decreased confluence of left-sided opacity, straight-edge effect along opacity's lateral margin, and evidence of bronchiectasis (arrowheads). Trachea deviates more to left than on previous radiographs. Right hilar vessels are now contracted against mediastinum (arrows).

D, CT scan obtained 3 years after treatment was completed shows left-sided opacity with bronchiectasis and a clearly defined lateral margin (arrowheads), representing radiation fibrosis. Hazy increased attenuation in right upper lobe was consistent with clinical findings of acute pneumonia at this time.

E, T2-weighted spin-echo MR image, 2000/70 (TR/TE), obtained 12 days before D shows left-sided radiation fibrosis with moderately high signal intensity as compared with muscle, bronchiectasis, and a morphologic appearance similar to that seen on CT. Thin band of bright signal (arrowheads) adjacent to aortic arch is of unclear significance and may be due to retained secretions. Lack of further change on subsequent CT scans indicated that this MR finding did not represent recurrent tumor.

Although these radiographic findings may resolve completely, progression to fibrosis usually occurs, particularly when the acute changes are severe [15, 25]. Radiation fibrosis tends to be established by about 9–12 months after treatment is completed [15]. The evolution of fibrosis is indicated by the appearance of more streaky opacities, volume loss, bronchiectasis, or pleural thickening on the affected side (Fig. 3C). When parenchymal opacities are minimal, cicatricial changes may represent the only sign of fibrosis, such as with the superomedial retraction of hila in patients who have undergone mantle irradiation for Hodgkin's disease [27]. One unusual manifestation of radiation fibrosis is the finding of a unilateral hyperlucent lung, presumably due to effects on central pulmonary vessels [28]. As in other fibrosing lung diseases, other complications may also occur, including spon-

taneous pneumothorax [29] and infection, such as with pulmonary aspergilloma [30].

Both acute and chronic radiographic changes are typically, although not always, confined to the treatment port, without respect for normal anatomic boundaries. With the evolution of fibrosis, demarcation between normal and irradiated lung parenchyma often becomes more sharply defined by a "straight-edge effect" (Fig. 3C), corresponding to what may be observed in pathologic specimens.

CT

More recently, the value of CT in showing manifestations of radiation-induced injury has been appreciated [31–38]. Libshitz and Shuman [32] described four CT patterns: (1) a

homogeneous, slight increase in attenuation, uniformly involving the irradiated portion of lung; (2) patchy consolidation within the irradiated lung, not necessarily conforming to the shape of the portal; (3) discrete consolidation, conforming to the shape of the portal, but not uniformly outlining it; and (4) solid consolidation, conforming to and totally involving the irradiated region of lung (Figs. 3D, 4, and 5). Patterns 1 and 2 appear to represent generalized and inhomogeneous radia-

tion pneumonitis, respectively. The third pattern may reflect focal organizing pneumonitis or fibrosis. The fourth pattern more clearly represents radiation fibrosis.

CT is more sensitive than chest radiography for showing radiation effects. Ikezoe et al. [35] noted that in 15 of 17 cases, abnormalities were apparent on CT within 16 weeks after radiotherapy; in 13 of these 15, changes were detected within 4 weeks. Moreover, in three of the 15 cases, abnor-

Fig. 4.—67-year-old woman with breast carcinoma that had metastasized to left upper lobe bronchus. A course of palliative radiation treatment (total dose, 3500 cGy) was given to left hilum.

A, 3½ months after treatment was completed, CT scan shows homogeneous slight increase in attenuation in left lung, consistent with radiation pneumonitis.

B, 3½ months after **A**, follow-up CT scan shows pattern of discrete consolidation with more clearly defined lateral margin (arrowheads), indicating progressive organization of left-sided opacity.

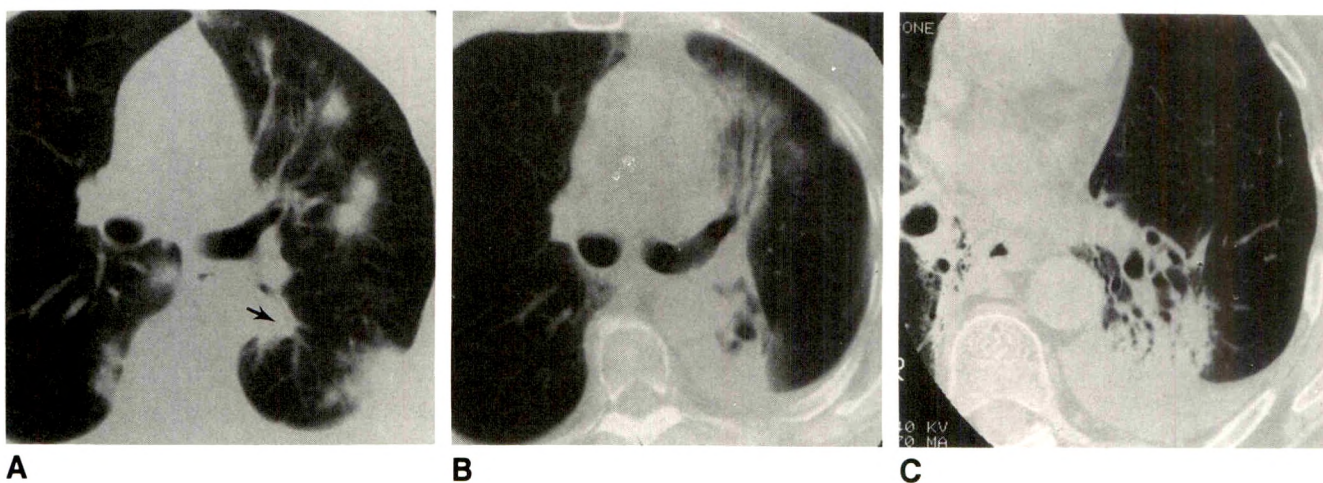
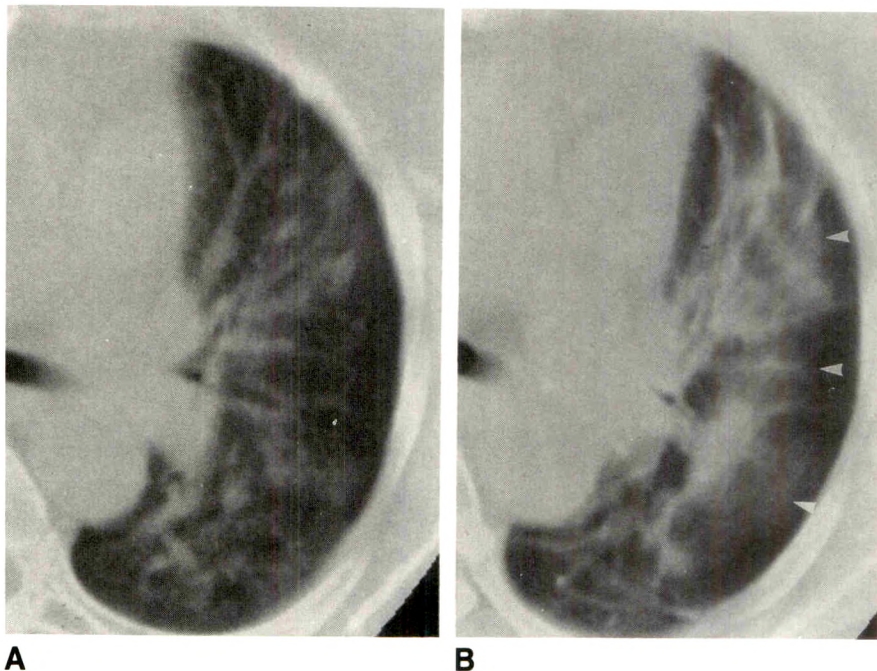
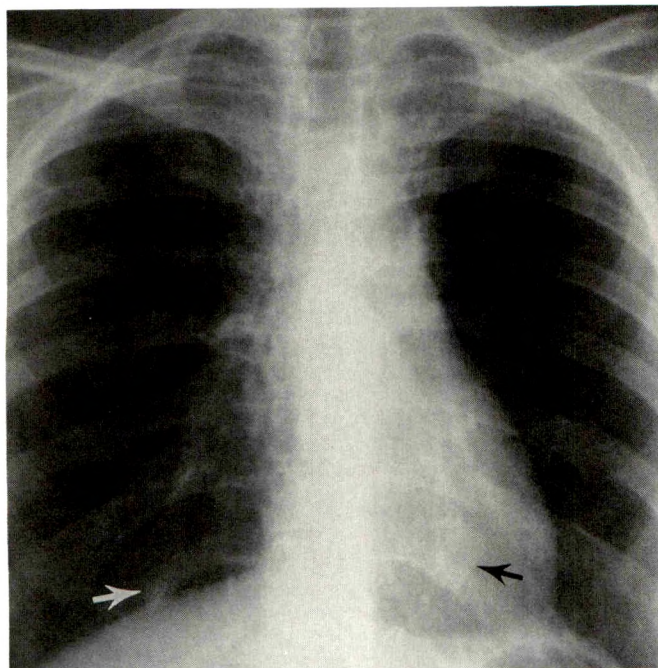


Fig. 5.—82-year-old woman with unresectable non-small-cell lung cancer.

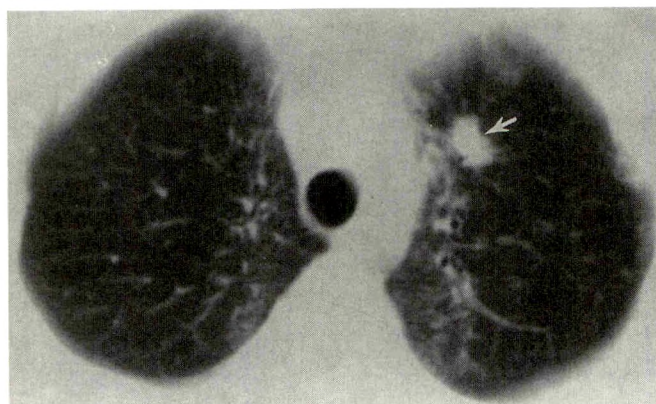
A, CT scan obtained 6 weeks after treatment was completed (total dose of 6000 cGy) shows a small residual tumor mass (arrow) in left paraaortic region. In left lung and medially in right lower lobe, poorly defined nodular parenchymal opacities lie within and roughly suggest outlines of radiation portal, in a pattern of patchy consolidation.

B, CT scan obtained 4 months after treatment was completed shows that parenchymal opacities have contracted toward mediastinum, appear more confluent, are associated with bronchiectasis, and more definitively outline radiation portal. Note new small left-sided pleural effusion; spontaneous reduction in this effusion on follow-up CT scan suggested it was most likely related to radiation pneumonitis.

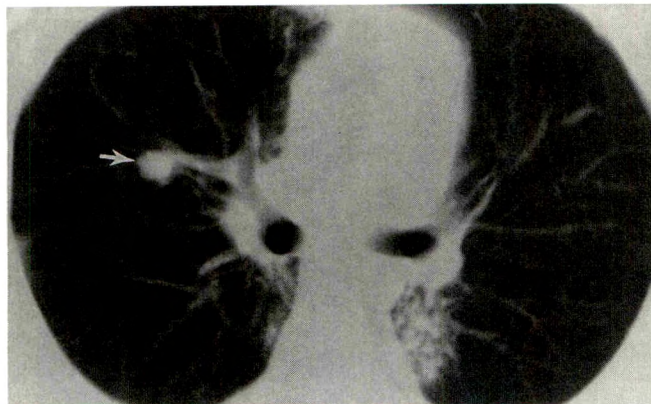
C, High-resolution CT scan obtained at a lower level than **B** shows bilateral paramediastinal opacities with bronchiectasis, in a pattern of solid consolidation. Note again left-sided pleural effusion.



A



B



C

Fig. 6.—28-year-old woman who received mantle irradiation for Hodgkin's disease (total dose of 4000 cGy).

A, Chest radiograph obtained 16 months after treatment was completed shows streaky opacities at both apices and upward and medial retraction of hila, consistent with radiation fibrosis. Bilateral pulmonary nodules (arrows) lying outside radiation field had appeared over a period of about 8 months before this examination.

B and C, Chest CT scans, obtained at same time as A, more clearly show radiation-induced changes at apices and in paramediastinal regions bilaterally, defined by straight-edge effect along portal margins. Parenchymal nodules (arrows) lying outside radiation portal are also better delineated. Open lung biopsy, within resection of a nodule in right lower lobe, showed recurrence of Hodgkin's disease within lung.

malities were not detected on chest radiographs, and in another three, findings were seen at an earlier time on CT. In the study of Bell et al. [36], chest CT scans were normal in only two of 39 patients, whereas chest radiographs were normal in more than half. The response of early radiation pneumonitis to corticosteroid therapy can be appreciated on serial CT scans. Ikezoe et al. [35] observed that 10 of 11 patients treated with corticosteroids had improvement of parenchymal opacities as shown by CT. Findings indicative of fibrosis, such as volume loss, pleural thickening, bronchiectasis, and cicatricial changes (e.g., displacement of vessels or fissures), are also better demonstrated on CT [33, 34, 37]. Furthermore, limited experience [35, 38] suggests that high-resolution CT is superior to conventional CT in showing subtle radiation effects, because of the better spatial resolution and avoidance of summation effects associated with the high-resolution technique.

CT is probably more specific than chest radiography in the diagnosis of radiation-induced injury. The straight-edge effect

is clearly seen on CT scans (Figs. 3D and 4–6). Unusual treatment ports are also well delineated. For example, the tangential-beam technique, used in the treatment of breast carcinoma, results in a characteristic CT appearance, with parenchymal opacities confined to the anterolateral subpleural region of lung [39]. Recognition of more complex portals may be facilitated by using computed dosimetric reconstruction, whereby treatment volumes are superimposed on axial CT scans [40].

Differential Diagnosis

Baseline and follow-up radiographic and/or CT examinations of the chest are of paramount importance in defining the distribution and sequence of observed changes. It is well known that parenchymal opacities from a radiation reaction are occasionally detected beyond the portal margin or in a bilateral distribution, both on chest radiographs [14, 17, 41] and on CT scans [33, 35, 36, 38]. Even within the treatment

port, opacities of radiation pneumonitis may sometimes appear nodular [31, 32] (Fig. 5A). Nevertheless, when an atypical radiologic appearance is observed, the possibilities of recurrent or metastatic neoplasm, infection, and drug-induced toxic effects should be considered. The presence of these potential complications may also be suggested by deviation from the expected temporal sequence for radiation effects, such as with the late appearance or enlargement of a pleural effusion or development of new consolidation, mass, or cavitation after a period when radiologic findings have been stable [10, 26, 31, 32, 34]. Definitive tissue diagnosis through bronchoscopy, percutaneous needle aspiration biopsy, open lung biopsy, or thoracentesis may be required (Fig. 6).

Subjects for Further Investigation

Imaging

MR imaging shows considerable promise in the diagnosis of radiation-induced lung parenchymal changes. Pathologic findings of proteinaceous exudate, inflammatory cell infiltrate, and eventual fibrosis should all be reflected in alterations of T1 and T2 relaxation times. Experimental work by Shioya et al. [42] with the irradiation of rat lung tissue has suggested that T2 is prolonged in the early stage of pneumonitis, corresponding to acute edema and inflammatory cell infiltration, and that T1 is shortened in the later stage of fibrosis, corresponding to increased deposition of collagen.

The major clinical application of MR has been distinguishing radiation fibrosis from recurrent tumor. Glazer et al. [43] reported that, particularly on T2-weighted images, radiation fibrosis had signal intensity similar to or occasionally lower than that of muscle, whereas tumor tended to have higher signal intensity relative to muscle; in no instance was the signal intensity of tumor less than or equal to that of muscle. On the other hand, radiation fibrosis may occasionally have high signal intensity on T2-weighted images, possibly because of (1) normal variation in the range of signal intensities, (2) persistence of an inflammatory component, (3) infection, or (4) hemorrhage [43, 44] (Fig. 3E). Werthmuller et al. [44] described two cases in which contrast enhancement occurred in regions of radiation-induced apical pulmonary fibrosis without recurrent tumor; in one patient, high signal intensity was present before administration of contrast material. These findings were attributed to the probable persistence of inflammatory cells within fibrotic tissue.

Charles et al. [45] have recently suggested that ^{31}P MR spectroscopy may be of further assistance in distinguishing tumor from fibrosis or other nonneoplastic entities, such as edema or necrosis. They reported that a superior mediastinal mass was ultimately proved at thoracotomy to represent inflammation and fibrosis without concomitant tumor or infection. A preoperative study had revealed moderately high signal intensity on T2-weighted images. However, on ^{31}P MR spectroscopy, the ^{31}P signal was low, consistent with a relatively low cellular density within fibrotic lung as compared with neoplastic tissue.

Gallium-67 scanning has been explored as a means of detecting early and subtle changes of radiation pneumonitis.

In a study of 12 cases of radiation pneumonitis, Kataoka et al. [46] observed ^{67}Ga uptake that was diffuse and bilateral in five cases and localized to the irradiated lung in seven. For the five cases with diffuse uptake, chest radiographs showed abnormalities on the irradiated side only. Histopathologic examination was possible in four cases and showed changes consistent with radiation-induced interstitial pneumonitis in the nonirradiated lung. Corticosteroids, administered in one case, resulted in clinical improvement and a return of the ^{67}Ga scan to normal, although the chest radiograph showed radiation fibrosis.

Pathogenesis of Radiation-Induced Lung Injury

Despite significant advances in imaging, the pathogenesis of radiation-induced injury remains unclear. One of the more intriguing questions is why a generalized pulmonary reaction to localized irradiation may occur. Recently, Byhardt et al. [47] reported findings consistent with an adult respiratory distress syndrome in two patients undergoing limited radiation treatment for lung cancer. Chest radiographs showed diffuse bilateral infiltrates, and, at autopsy, hyaline membranes were found within both the irradiated and nonirradiated volumes of lung.

Possible explanations for such generalized effects are (1) blockage of lymphatic channels, impeding egress of alveolar macrophages [41]; (2) errors in dosimetry or placement of ports [14], scattered radiation [48], or a sensitizing effect of concomitant infection [14, 48]; and (3) individual hyperreactivity [8, 14, 46, 48]. The last hypothesis has found the most favor. Some persons may have an inherent genetic susceptibility to the effects of irradiation [48, 49]. Alternatively, an immunologically mediated reaction may occur. Gibson et al. [48] performed bronchoalveolar lavage in four patients who had unilateral radiation pneumonitis after treatment for carcinoma of the breast. For both the irradiated and nonirradiated lungs, examination of the lavage fluid showed an increase in the total number of cells recovered and a marked lymphocytosis. ^{67}Ga scanning also showed bilateral uptake of the radionuclide, although chest radiographs showed abnormalities on the irradiated side only. These authors postulated that the observed lymphocytosis might reflect a hypersensitivity pneumonitis, perhaps arising from a radiation-induced release of lung antigens or imbalance among T-lymphocyte subsets.

Conclusions

Radiologic imaging of the chest, performed at arbitrary intervals after radiation treatment is completed, reflects a continuum of histopathologic findings for radiation-induced lung injury, as represented by exudative, organizing, and fibrotic phases. Imaging studies are of critical importance in diagnosing radiation effects, as neither clinical signs and symptoms nor alterations in pulmonary function tests may indicate the presence of radiation pneumonitis or radiation fibrosis. Radiologic findings are not specific, however, and careful attention should be paid to the distribution and temporal sequence of changes in order to differentiate radiation

effects from possible infection or a malignant neoplasm. Careful analysis of treatment ports through computed dosimetric reconstruction, as well as further applications of MR imaging, may help increase the confidence with which radiation effects are recognized and, in some cases, may even obviate invasive diagnostic procedures. Early detection of radiation pneumonitis, perhaps by using CT, high-resolution CT, or ^{67}Ga scanning, is important if prompt treatment is to be instituted. These imaging techniques can also be used to show a response to corticosteroid therapy. Further clarification of factors involved in the pathogenesis of radiation-induced injury is essential if this complication is to be avoided, or at least anticipated.

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Review Article

Epilepsy: The Role of MR Imaging

Richard A. Bronen¹

MR is the imaging technique of choice when examining a patient who is having seizures. Detection, localization, and differentiation of structural epileptogenic abnormalities are much better with MR imaging than with CT. MR imaging has a high success rate in identifying hippocampal sclerosis, a common cause of surgically treatable temporal lobe epilepsy. The affected hippocampus is atrophic and hyperintense on long TR images. Functional imaging with single-photon emission computed tomography and positron emission tomography is complementary to MR imaging but is not as widely available.

In summary, MR imaging has dramatically changed the workup of epilepsy, especially for the patient with medically uncontrollable seizures. As surgical treatment of epilepsy becomes more available, the need for preoperative evaluation with MR imaging will increase.

The role of imaging in the evaluation of epilepsy is to localize the origin of a focal seizure and identify its cause. This information is important in the treatment and prognosis of affected patients, but is vital to those with surgically treatable epilepsy. Since its development one decade ago, MR imaging has revolutionized the evaluation of epilepsy. MR imaging is clearly superior to CT for detection of epileptogenic structural abnormalities. Physiologic imaging provided by single-photon emission computed tomography (SPECT) and positron emission tomography (PET) provides information that is complementary to MR imaging findings. However, the physiologic changes seen with SPECT and PET may be more widespread and less specific than the focus defined when using MR

imaging, electroencephalography (EEG), and surgery. As most clinical questions relate to the cause of the seizure, MR imaging appears to be more useful than PET or SPECT for routine diagnosis [1]. These considerations, accompanied by the widespread accessibility of MR, have made MR the imaging study of choice for the assessment of epilepsy. This article will review the application of MR imaging to epilepsy, with emphasis on hippocampal sclerosis.

Overview of Epilepsy

Epilepsy affects 0.5–1.0% of persons in the United States. It can be categorized as either partial (focal) or generalized (Table 1). Partial epilepsy can be further classified as partial simple (with no impairment of consciousness), partial complex (with impairment of consciousness), or partial epilepsy that secondarily generalizes [2]. The most common location for epileptogenic foci is in the temporal lobe, represented clinically as temporal lobe epilepsy.

Approximately 10–30% of epilepsy cases are refractory to medication. It is estimated that there may be as many as 200,000 potential candidates for epilepsy surgery in the United States [3]. Surgical treatment of certain disorders such as tumors, vascular malformations, or hippocampal sclerosis can eliminate seizure activity. Because the type of surgery and the outcome depend on the cause and location of the epileptogenic source, MR imaging has become a critical component of the preoperative evaluation.

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TABLE 1: Seizure Classification in 1220 Adults

Seizure Type	%
Partial	
Simple partial	8
Complex partial	23
Partial with secondary generalization	26
Total	56
Generalized	
Absence	1
Atypical absence	<1
Tonic-clonic	23
Tonic or clonic	<1
Atonic	<1
Myoclonic	1
Total	26
Unclassified	18

Note.—Reprinted with permission from Keränen et al. [2].

Cause of Epilepsy

The relationship of the origin of a focal seizure, the epileptogenic focus, to a structural lesion is based on three assumptions: (1) partial seizures are due to a pathologic abnormality, thus there is always a lesion; (2) if a lesion can be shown in a patient with seizures, then it is highly probable that seizures are the result of that lesion; and (3) the seizure focus originates in the vicinity of the lesion, but the precise site and extent of the seizure focus is not necessarily the same as that of the lesion [4].

Support for the concept of the epileptogenic focus is available from imaging studies. Partial epilepsy, as opposed to primary generalized epilepsy, is often associated with a structural abnormality of the brain [5]. As the contribution of MR imaging is in the identification of structural abnormalities, one might be tempted to image only those patients with partial epilepsy. However, distinguishing patients with rapid secondary generalization from those with true primary generalization by using clinical criteria or scalp EEG can be difficult, especially in children. For this reason, many neurologists use MR imaging to screen all children who are having seizures.

The cause of epilepsy depends on the characteristics of the population studied, such as seizure classification, patient's age, and response to medical treatment [6] (Table 2). In a large pre-CT study of 516 patients treated for epilepsy from 1935 to 1967, a specific cause was found in 23%: trauma, 5%; vascular, 5%; neoplastic, 4%; congenital, 4%; infection, 3%; birth anoxia, 1.4%; and degenerative, 0.6% [7]. The best available pathologic correlation is found in patients successfully treated by surgery. Seizure elimination implies that the seizure focus (or circuit) has been identified and resected. Obviously this is a biased conclusion, because these patients are not helped by medical treatment. But it is precisely this group of persons that benefits most from imaging. In surgical studies investigating intractable epilepsy (mainly temporal lobe epilepsy), hippocampal sclerosis is the most common cause (50–70%), followed by perinatal anoxia/injury (13–35%), tumors (15%), vascular malformations (3%), traumatic scarring (2%), and hamartomas (2%) [8–17]. Abnormalities found in less than 1% include infection, migrational

TABLE 2: Cause of Epilepsy Categorized by Age at Onset of Seizures

Cause	Age (yr)				
	0–2	3–20	21–40	41–60	>60
Anoxia	Yes				
Metabolic abnormalities or in-born error of metabolism	Yes				
Congenital or developmental malformations	Yes	Yes			
Infection	Yes	Yes			
Phakomatosis	Yes	Yes			
Primary generalized seizures		Yes			
Hippocampal sclerosis		Yes			
Trauma	Yes	Yes	Yes	Yes	
Vascular malformation			Yes		
Tumor			Yes	Yes	Yes
Cerebrovascular accident				Yes	Yes

Note.—Phakomatoses include tuberous sclerosis, Sturge-Weber syndrome, and neurofibromatosis.

disorders, tuberous sclerosis, cortical dysplasia, cysts, and infarcts. In one fourth of cases, the findings are nonspecific or normal. Dual abnormalities are found in 8–22%, usually consisting of hippocampal sclerosis in combination with either glioma, hamartoma, or heterotopia [8]. The most common tumor type is the low-grade astrocytoma. Other prevalent types include higher grade astrocytomas, oligodendrogliomas, and gangliogliomas. Meningiomas and epidermoids occur less frequently in patients with chronic epilepsy.

Imaging of Patients with Epilepsy

Overview

In patients with intractable epilepsy, most reports indicate that a focal abnormality is discovered with CT in approximately one fourth of patients and with MR imaging in one half of patients [18–27]. It is difficult to compare PET and SPECT with MR imaging. Thin-section coronal MR imaging with assessment of the hippocampus in patients with temporal lobe seizures has not been done in studies that compared these techniques. Most PET studies have investigated metabolic changes in temporal lobe seizures by using fluorodeoxyglucose. Interictally, decreased regional cerebral metabolism is observed in 55–80% of patients. The hypometabolic zones seen on PET are usually larger than the region of seizure focus identified electrically or the structural abnormality found with CT or MR. During focal seizures, hypermetabolic activity is seen at the formerly hypometabolic site, but may also be seen in areas where seizures propagate. Compared with MR imaging, PET scanning is expensive and not widely available [1, 28–30]. SPECT takes advantage of cerebral blood flow changes that usually accompany changes in metabolism; thus, SPECT findings are similar to PET findings. Hypoactivity or hypoperfusion is observed in the region of seizure focus during interictal studies in at least 50% of patients. Immediate postictal SPECT images, which demonstrate hyperperfusion, appear to be even more accurate. Compared with PET, SPECT imaging suffers from decreased resolution and lack of absolute quantitative data [1, 28].

Most MR imaging studies, especially the earlier ones, were concerned only with abnormal signal changes as evidence of a lesion. Hippocampal size is an important criterion that often has been overlooked. MR imaging may be able to locate the seizure focus in three fourths of patients with refractory epilepsy, as demonstrated by Kuzniecky et al. [16] ($n = 48$). MR imaging is unsurpassed for the detection of structural lesions such as tumors, vascular malformations, hamartomas, heterotopic gray matter, and atrophic lesions. This is especially true in the temporal lobe, where bone artifact on CT may obscure the abnormality. Sperling [1] believes that CT is superfluous in the workup of the epilepsy patient and should be performed only to clarify an MR imaging finding.

Gadopentetate dimeglumine does not appear to be routinely required in the MR workup of patients with chronic partial epilepsy, because it has not significantly improved detection rates in this population [31, 32]. As seizure localization is determined by clinical and physiologic criteria, an anatomic abnormality shown by imaging may not necessarily be the site of seizure focus. All the available data should be integrated. Conversely, MR imaging may locate the epileptogenic lesion while scalp EEG indicates the focus is not localized or is contralateral [18, 25, 33].

MR Imaging Findings

Acquired epileptogenic lesions include tumors and atrophic processes caused by perinatal anoxia, infection, or trauma [13, 34]. Tumors have a variable appearance, often depending on composition, such as cysts, calcium, or hemorrhage [35, 36] (Fig. 1). Most do not enhance with contrast administration and are not associated with edema. As epilepsy is a cortical process, these tumors are usually found within the subcortical white matter or the cortical gray matter. Seizure duration of a decade in these patients is common, and it could span 30 years [9]. Thus, neither a long history of seizures nor a cortical location should prevent one from considering the diagnosis of tumor. In fact, the chronicity and peripheral location of these lesions sometimes lead to reshaping and thinning of the calvaria, a finding that is distinctly unusual for an intraaxial lesion (Fig. 2). Surface EEG is often unreliable for localization in these patients [37].

Congenital lesions associated with seizures include glial hamartomas, vascular malformations, developmental anomalies, and migrational disorders. Heterotopic gray matter represents cortical neurons in an abnormal location owing to abnormal migration of neuroblasts from ventricle to brain

Fig. 1.—Oligodendroglioma.

A, Although artifact obscures left temporal lobe on axial CT scan, abnormal calcification (arrow) is present.

B, T2-weighted coronal MR image shows a large heterogeneous mass occupying much of temporal lobe. Central signal void corresponds to calcification seen on CT (black arrow), while peripheral signal void (white arrow) is from prior tumoral hemorrhage and deposition of hemosiderin. Cystic areas were isointense with respect to CSF on all pulse sequences.

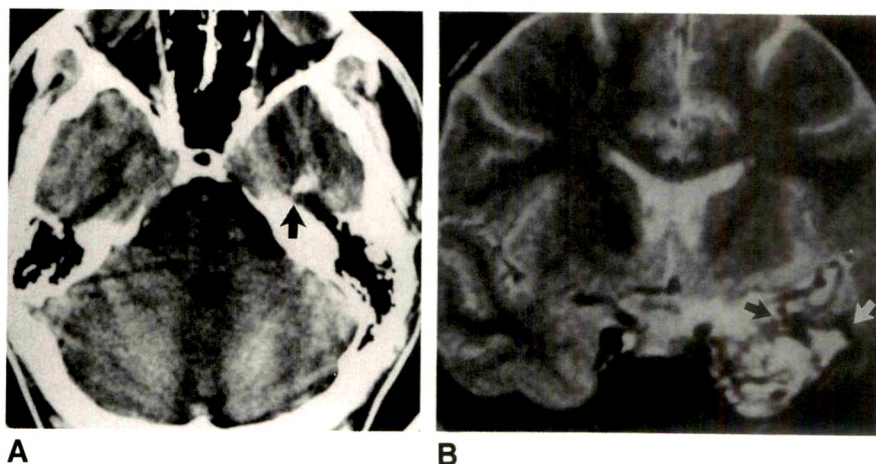
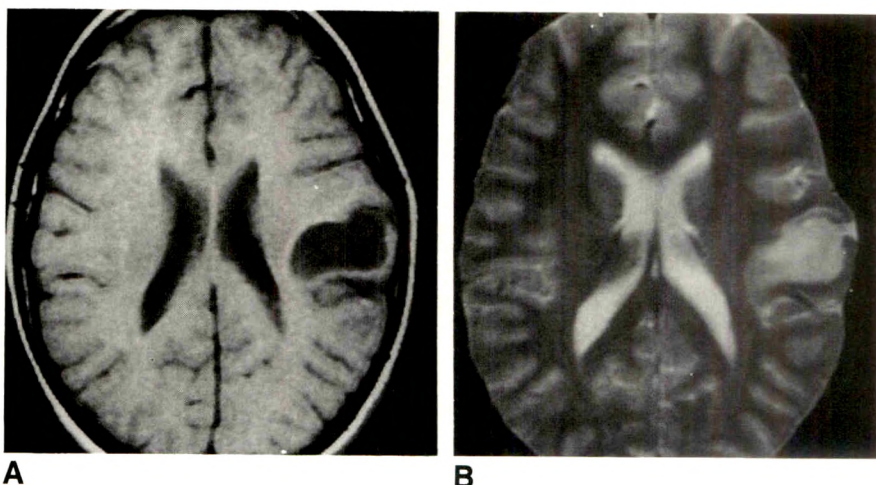


Fig. 2.—Low-grade glioma.

A and B, T1-weighted (A) and T2-weighted (B) axial MR images show a large cystic tumor in subcortical white matter that has expanded surface contour of brain, thinning and reshaping adjacent calvaria.



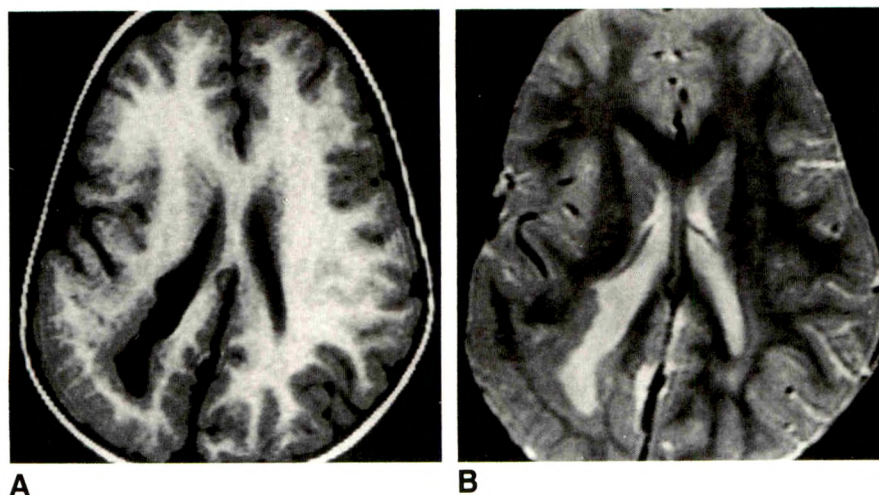


Fig. 3.—Heterotopic gray matter.
A and B, T1-weighted (A) and T2-weighted (B) axial images display a nodular rim of tissue around atrium of right lateral ventricle that is isointense with respect to gray matter. This is a common location. Note adjacent thickened cortex, also representing a migration disorder.

surface. Heterotopia is typically found adjacent to the lateral ventricles or within the white matter close to the sylvian fissure. These lesions are isointense with respect to gray matter on all pulse sequences (Fig. 3). Heterotopia is probably a more common cause of seizures than is appreciated; it was frequently not diagnosed prior to the era of MR imaging. Other developmental anomalies associated with seizures include pachygyria, schizencephaly, lissencephaly, hemimegalencephaly, anterior temporal lobe encephaloceles, and cortical dysplasia. These anomalies have recognized MR findings [34, 38–45].

Transient signal abnormalities have been described in patients with seizures. The causes appear to be diverse. Reports from India and Mexico indicate these findings are probably related to infectious disorders, especially tuberculosis and cysticercosis. Other reports have correlated prolonged seizure activity to these abnormalities, especially in patients with focal status epilepticus. Resolution of imaging abnormalities has paralleled clinical activity. One should be cautious in recommending invasive procedures when MR abnormalities are found during frequent seizures. These findings may be related to focal cerebral edema during an ictus. Attempts to correlate experimental seizure foci with MR imaging changes have been unsuccessful. Interictal cortical foci created in rats have not produced signal abnormalities detectable with MR imaging [46–52].

Hippocampal Sclerosis

This section reviews the importance of hippocampal sclerosis, the anatomy of the hippocampus, and finally MR imaging of hippocampal sclerosis.

Overview of Hippocampal Sclerosis

Hippocampal sclerosis is the most common entity associated with medically intractable temporal lobe epilepsy. It is also referred to as mesial temporal sclerosis or Ammon's horn sclerosis. Regional neuronal loss and gliosis lead to reorganization of neuronal circuitry within the hippocampus, which

consequently results in an epileptogenic focus. As treatment of hippocampal sclerosis by surgical resection is associated with a very good outcome, preoperative diagnosis is extremely important.

This entity can be characterized by the following findings or associations: marked hippocampal neuronal depletion, in the range of 30–50% compared with control subjects; loss of inhibitory hippocampal interneurons; synaptic reorganization; a seizure focus arising from the hippocampus; a history of febrile seizures; and cure or elimination of 90% or more of seizures with surgical resection of the hippocampus and anterior temporal lobe [8, 53–57]. Sixty-five percent of patients with intractable temporal lobe epilepsy are found to have hippocampal sclerosis in surgical and autopsy studies [8]. One postulated mechanism is that a precipitating event in the developing brain of an infant, such as a severe febrile seizure, damages the inhibitory interneurons. This may increase the electrical input into the hippocampus so that it overloads and damages other hippocampal neurons. The concomitant reorganization of neuronal circuitry and changes in neuronal excitability result in a hyperactive focus—the epileptogenic focus. The extensive connections between the hippocampus and the remainder of the brain help to propagate the seizure focus [54].

Hippocampal Anatomy

Interpretation of MR findings associated with hippocampal sclerosis requires an understanding of the complicated hippocampal anatomy. The terminology is often confusing [58]. The terms hippocampal formation and hippocampus are used interchangeably. The hippocampus is an arched structure found on the medial surface of the temporal lobe. The hippocampus undergoes a radical change in size and shape from anterior to posterior (Fig. 4) [59–63]. It can be divided into three segments on the basis of its shape and relationship to the brainstem: the bulbous head, the uniform body, and the narrow tail. The head is found at the anterior edge of the brainstem, the body is adjacent to the brainstem, and the tail is found ascending and curving behind the brainstem. The

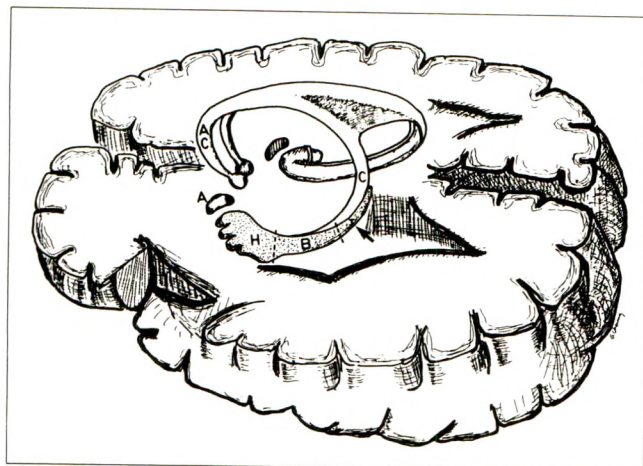


Fig. 4.—Hippocampus and fornix above base of brain. Hippocampal head (H) is bulbous and digitated. Body (B) is fairly uniform and horizontal. Tail (arrow) tapers markedly as it ascends vertically. Amygdala (A) is anterior to hippocampus. Main efferent hippocampal pathway consists of fimbria, which becomes fornix (C and AC). (Reprinted with permission from Bronen and Cheung [59].)

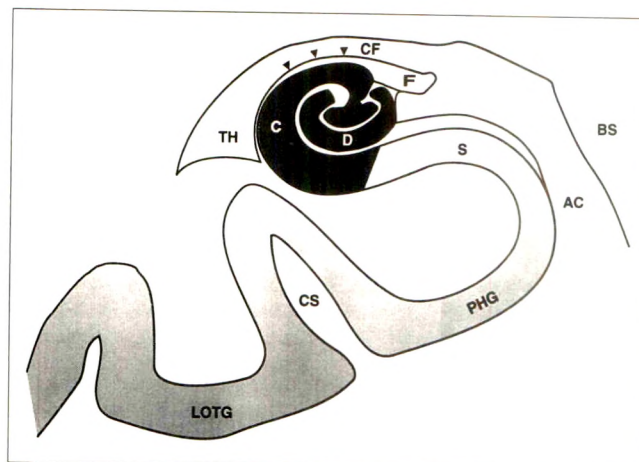


Fig. 5.—Drawing of right hippocampal formation and medial temporal lobe. Cornu Ammonis (C) and dentate gyrus (D) form two interlocking C-shaped laminae of gray matter. Hippocampal formation is covered by white matter of alveus (arrowheads), which forms fimbria (F) medially. CF = choroidal fissure, TH = temporal horn of lateral ventricle, BS = brainstem, S = subiculum, AC = ambient cistern, CS = collateral sulcus, PHG = parahippocampal gyrus, LOTG = lateral occipital temporal gyrus.

head can be identified by prominent notches or digitations. The resemblance of these digitations to toes of the foot led to the term *pes hippocampi*, a synonym for the hippocampal head [61]. The body is the truly horizontal portion of the hippocampus. This is the most reliable region in which to quantitatively assess the hippocampus histopathologically and with MR [64]. The tail dramatically tapers as it courses behind the brainstem.

The hippocampal formation is a complex functional unit composed predominantly of two C-shaped interlocking gray matter structures, the cornu Ammonis and dentate gyrus. This is best appreciated in the coronal plane (Fig. 5). The fornix, alveus, and fimbria are the major white matter tracts of the hippocampal formation, forming the main efferent pathway from this region. Adjacent structures include, inferiorly,

the parahippocampal gyrus, connected to the hippocampus via the subiculum; medially, the ambient (perimesencephalic) cistern, separating the medial aspect of the hippocampus from the brainstem; superiorly, the choroidal fissure and temporal horn of the lateral ventricle; and laterally, the temporal horn [60–63].

On coronal MR images of healthy subjects, the hippocampi are symmetric oval structures along the medial temporal lobe, isointense with respect to gray matter [65]. The head is identified by visualization of its digitations. It is found on those slices that include the basilar artery or interpeduncular cistern (Fig. 6). The body is situated adjacent to the midbrain (Fig. 7). The tail of the hippocampus is located at or behind the midbrain colliculi and is vertical in orientation. Anterior to the hippocampus is the amygdala, separated by the temporal

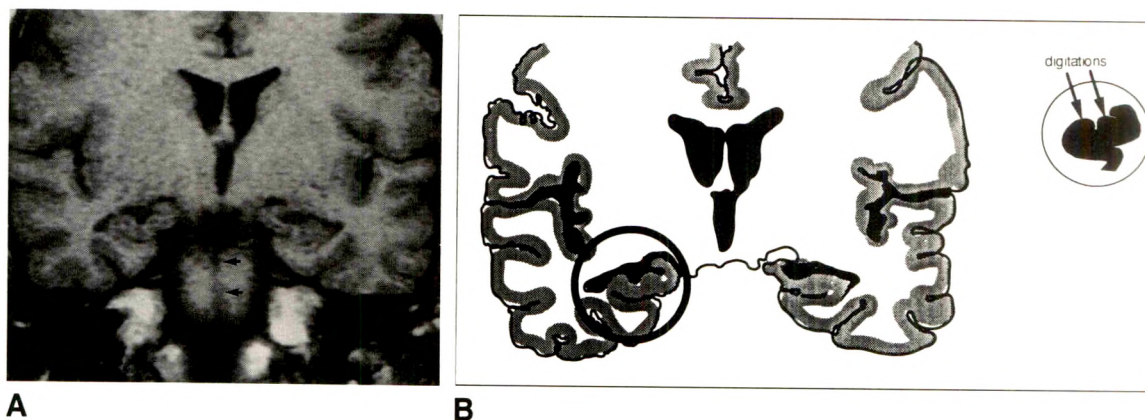


Fig. 6.—Normal hippocampal head.
A, Normal hippocampal head identified by digitations on T1-weighted coronal MR image. Arrows point to basilar artery. (Reprinted with permission from Bronen and Cheung [59].)
B, Diagram of hippocampal head in A; arrows in insert point to digitations, which are unique to head.

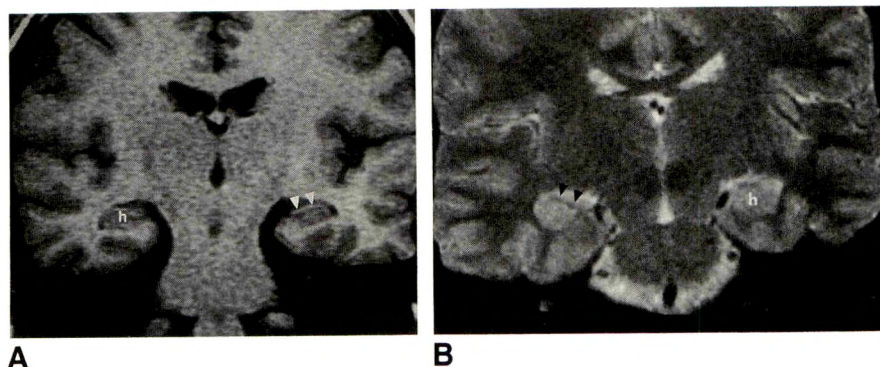


Fig. 7.—Normal hippocampus at level of body. A and B, T1-weighted (A) and T2-weighted (B) coronal images show oval gray matter of hippocampus (h) capped superiorly by white matter of alveus and fimbria (arrowheads). (Reprinted with permission from Bronen and Cheung [59].)

horn of the lateral ventricle. The gray matter of the more lateral amygdala is inseparable from the uncus on MR imaging [59, 62, 63].

Imaging Parameters

Because of anatomic considerations, MR imaging findings are best identified on nonorthogonal coronal T1-weighted scans perpendicular to the long axis of the hippocampus. This can be achieved with routine spin-echo sequences [66]. However, orthogonal scans obtained with techniques such as three-dimensional (3D) spoiled gradient imaging (SPGR) or 3D fast low-angle shot are preferential because of their superior gray-white matter differentiation and capacity for thinner slice thickness [64, 67]. The thin slices improve confidence in detecting asymmetry. In patients with epilepsy, we currently image the entire brain by using coronal SPGR sequences with a 1.5- to 3-mm slice thickness. Long TR scans in the axial and coronal planes also are obtained. Other useful sequences include long TR fast spin echo for increased spatial resolution and gradient-echo images for detecting lesions that have hemorrhaged.

MR Imaging of Patients with Hippocampal Sclerosis

An asymmetrically small or atrophic hippocampus ipsilateral to the seizure focus is the most significant MR finding. This is often associated with increased signal within the affected hippocampus on T2-weighted images. These findings may be subtle [64] (Figs. 8–11). In recent MR studies of histologically proved hippocampal sclerosis, findings were abnormal in 62–100% of patients [13, 15, 16, 64, 68–71]. In 41 patients who underwent epilepsy surgery, Jackson et al. [70] reported a 93% sensitivity and 86% specificity for MR in the diagnosis of hippocampal sclerosis. A specific finding of hippocampal atrophy has been noted in a combined total of 32 of 34 patients from three studies with histologic correlation [64, 69, 71].

In histologically confirmed cases, a hyperintense hippocampus was visualized in none of 18 cases (performed with a low-field-strength magnet) [72] and in three of 38 [10], three of 11 [13], eight of 13 [15], seven of nine (including two subtle findings) [64], and nine of 10 [69]. Kuzniecky et al. [16] postulate that the signal abnormality is due to gliosis, edema,

or both. The most common region of abnormality is at the hippocampal body [64, 70]. The hyperintensity is usually confined to the hippocampus, without extending beyond its boundaries.

Other imaging findings are less reliable for detecting hippocampal sclerosis. These include ipsilateral temporal lobe atrophy and ipsilateral temporal horn dilatation [10, 16, 50, 64, 66]. These should be used as secondary signs of hippocampal sclerosis because mild asymmetry of these structures occurs normally [66, 68, 73–75]. However, the use of multiple MR criteria can increase the confidence of diagnosis [50, 64] (Fig. 8). CT and angiography are poor methods for detecting hippocampal sclerosis [5, 16, 50, 64, 72].

Quantitative MR volume studies have increased the detection rate and reliability for diagnosing pathologically proved or probable hippocampal sclerosis, with reported sensitivities of 74–96% and specificities of 73–100% [66–68, 71]. Jack et al. [66] correctly identified the epileptogenic hippocampus in 76% of patients with presumed hippocampal sclerosis when using computer quantification of size compared with 68% when using visual assessment of size asymmetry. Reductions of 30–35% in hippocampal volume on the involved side have

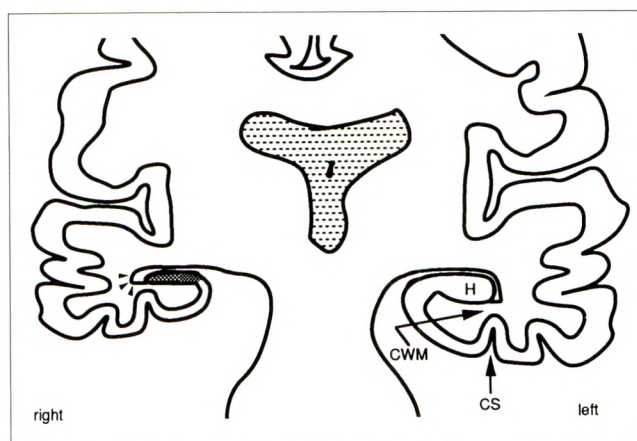


Fig. 8.—Diagram of idealized right hippocampal sclerosis on a coronal MR image. Right hippocampus is atrophic and hyperintense (shaded area). Ipsilateral temporal lobe and collateral white matter are asymmetrically small, while temporal horn (arrowheads) is enlarged. H = hippocampus, CWM = collateral white matter, CS = collateral sulcus. (Modified with permission from Bronen et al. [64].)

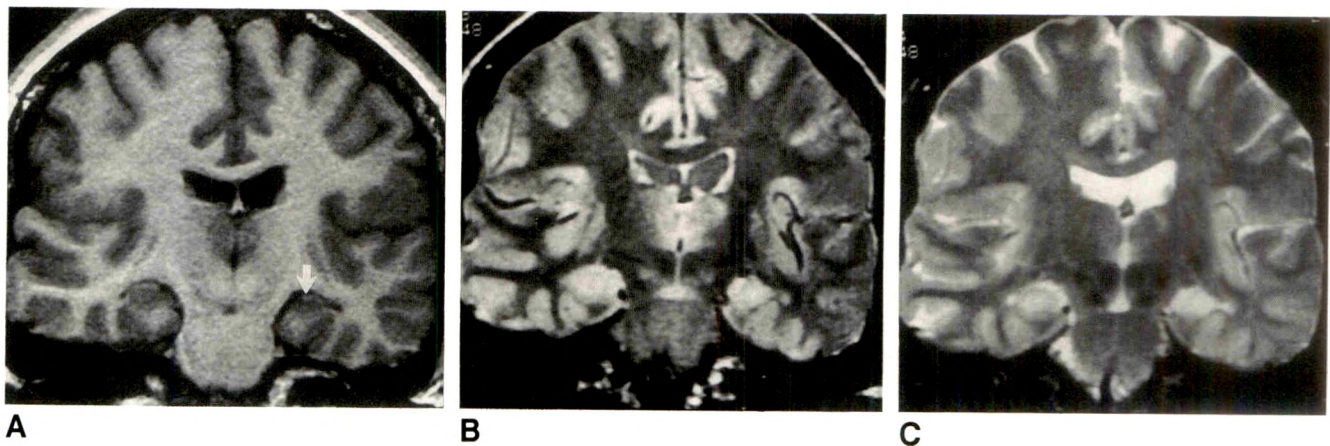


Fig. 9.—Histologically confirmed left hippocampal sclerosis.

A–C, T1-weighted (A), proton density-weighted (B), and T2-weighted (C) coronal MR images at hippocampal body. Atrophy of hippocampal gray matter (arrow) on left side (compared with normal hippocampus on right) is best depicted on T1-weighted coronal images. Hyperintense hippocampal signal is usually better seen on longer TE images, as noted in C. One should be careful not to confuse this with CSF signal in adjacent temporal horn (compare A, B, and C).

Fig. 10.—Histologically confirmed right hippocampal sclerosis.

A and B, T2-weighted coronal MR images at hippocampal tail (A) and body (B). Right hippocampus is atrophic and slightly hyperintense (arrow). Atrophy of adjacent collateral white matter (arrowheads) has obscured borders between hippocampus and temporal lobe cortex more anteriorly at level of body (B). Here, atrophic hippocampus could easily have been overlooked if severe collateral white matter atrophy was not noticed. (Reprinted with permission from Bronen et al. [64].)

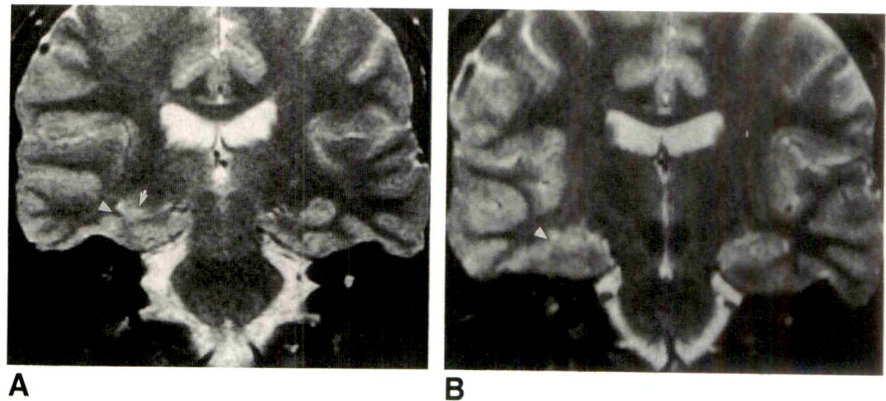
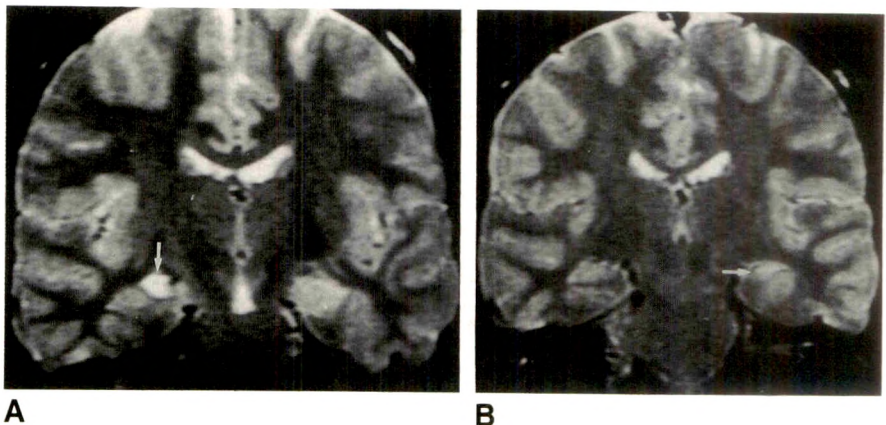


Fig. 11.—Histologically confirmed left hippocampal sclerosis. A cyst or glioma in right temporal lobe of patient with a left electroencephalographic (EEG) focus was seen on axial CT scan (not shown).

A, T2-weighted coronal MR image at hippocampal body shows this to be an incidental right choroidal fissure cyst (arrow).

B, T2-weighted coronal MR image more posteriorly shows source of epilepsy, a hyperintense, atrophic left hippocampus (arrow). This case illustrates the fallacy of using MR (or CT) to investigate seizures without EEG correlation.

(Reprinted with permission from Bronen et al. [64].)



been reported [67]. The degree of hippocampal atrophy seen on preoperative MR images has been correlated with the number of neurons in postsurgical specimens [64, 68]. Quantitative studies of the temporal lobe are less sensitive.

Most reports have concentrated on the group of patients with medically intractable epilepsy, those who are examined

for possible surgical control. Triulzi et al. [76] found similar MR findings in patients with medically well-controlled temporal lobe epilepsy. It appears that hippocampal sclerosis may not always develop into severe refractory epilepsy.

Although divergent results have been published, it now appears clear that MR imaging is very good at showing

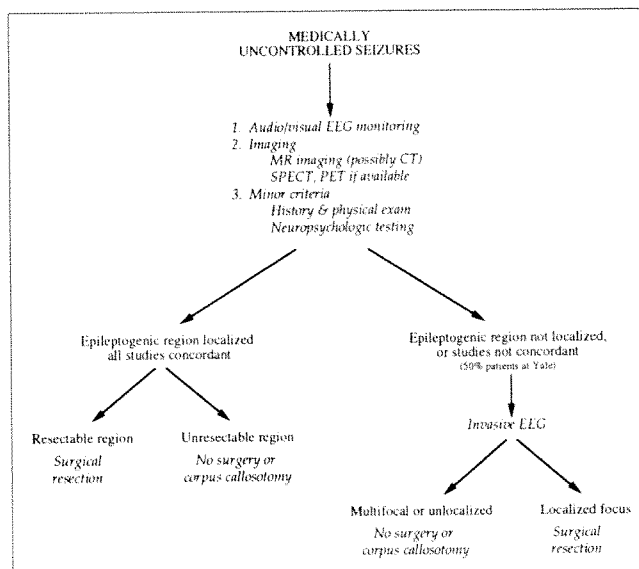
evidence of hippocampal sclerosis and for use in differentiating it from other causes. Poor yields in earlier studies may have been due to inferior scanners, reliance on axial images, or lack of assessment of hippocampal size [10, 72]. Hippocampal sclerosis not only can be shown with MR imaging, but also can be distinguished from tumors and hamartomas [13, 64, 70]. An abnormal signal associated and confined to a small shrunken hippocampus is not seen with tumors. However, MR imaging findings must correlate with clinical, EEG, and other relevant data to be reliable. This is especially true in cases of dual pathologic findings. Hippocampal sclerosis has been found in association with heterotopia or other lesions, such as tumors, hamartomas, or cysts [8, 11, 55, 64, 77–79]. Conversely, one should always evaluate the hippocampi in patients with epilepsy even if a lesion is found; it may be a nonepileptogenic incidental lesion (Fig. 11).

Implications of Neuroimaging for Epilepsy Surgery

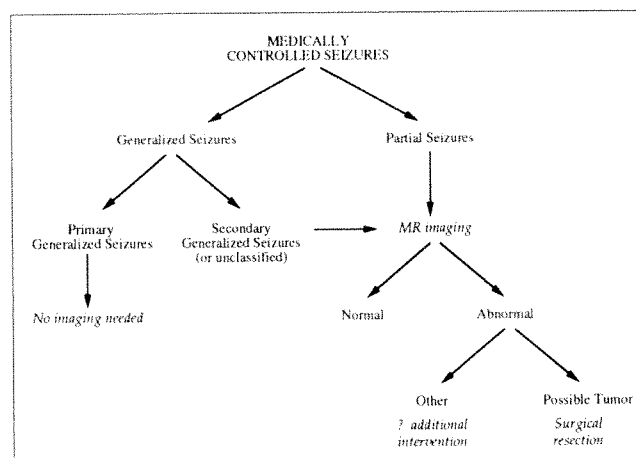
Prior to neuroimaging, surgical resection for epilepsy was based on EEG and clinical characteristics. However, since EEG abnormalities can propagate widely, this can result in false lateralizing and false localizing information. False localization from scalp EEG occurs in 10–15% of patients [29]. Depth EEG alters surgical plans in 50% of patients examined for diffuse or multifocal scalp EEG patterns [80]. Thus, invasive EEG, in the form of intracranial depth or subdural electrodes, has been required for confirmation of the seizure focus preoperatively. This is especially true for temporal lobe epilepsy and hippocampal sclerosis. Invasive EEG is associated with a 2–5% complication rate, additional hospitalization, and increased financial costs [81, 82].

Neuroimaging techniques have radically changed the pre-surgical examination of the epilepsy patient because they can markedly enhance confidence in the localization derived electrophysiologically. They increase confidence in the localization based on noninvasive tests, allowing surgical resection to be performed without preoperative invasive studies. Neuroimaging can help in planning appropriate intracranial electrode recording when this type of testing is necessary. Imaging findings may favor surgery in some patients who otherwise might be rejected for surgery [29].

The algorithm for determination of seizure focus and resection procedure varies depending on institutional philosophy and availability of resources, such as PET or SPECT. Depending on the institution, PET, SPECT, MR imaging, or a combination of the three techniques may be relied on for neuroimaging. Most centers base their decisions on clinical evaluation, neuropsychological testing, baseline scalp EEG, 24-hr continuous audio/visual monitoring (to record at least three seizures), cerebral amobarbital testing, and neuroimaging. If all these preoperative localizing data suggest the same location, then invasive EEG studies before surgery may not be necessary. If any of these tests are not concordant, then invasive monitoring is indicated (Fig. 12) [29, 80, 82, 83]. MR findings can change the decision tree if a lesion thought to be a glioma is detected. If resectable, the patient will have surgery.



A



B

Fig. 12.—Decision tree for imaging and surgical intervention in epilepsy.
A, Decisions for patients with medically uncontrolled seizures are driven principally by electroencephalographic (EEG) and imaging findings. Data from history and physical and neuropsychological examinations are important for their contradictory rather than confirmatory information. If these sets of data are concordant with a localized epileptogenic region, then patients can have surgery immediately. Otherwise, invasive EEG studies are indicated.

B, In patients with medically controlled seizures, identification of the cause by MR rarely leads to further medical intervention except in the case of tumors or possibly arteriovenous malformations. As it is often difficult and time-consuming to distinguish primary from secondary generalized seizures, many neurologists opt to use MR imaging as part of a screening workup for patients with generalized seizures that are not unequivocally of the primary type.

The current role of individual imaging techniques is in flux. MR appears to have replaced CT for most epilepsy imaging [1]. Volumetric analysis of the hippocampus with MR increases the likelihood of correctly lateralizing temporal lobe epilepsy and hippocampal sclerosis compared with qualitative assessments. As a research tool, volumetric analysis probably should be performed in patients in large surgical epilepsy programs. Qualitative evaluation still yields sensitivities of

greater than 70%. Compared with PET scanning, MR imaging is much more available and is better for defining origin, location, and extent of structural lesions. Thus, MR imaging may be more useful than PET or SPECT for routine needs in the diagnosis of epilepsy [1]. As mentioned, there are no good studies comparing the sensitivity of MR with PET or SPECT. Coupling structural to functional data appears possible as a result of recent advances with techniques such as echoplanar MR imaging and coregistration of MR to PET and SPECT [84, 85].

In summary, MR, along with PET and SPECT, has decreased the number of preoperative invasive tests, increased the number of surgical candidates, and increased the precision of surgical resection. This is particularly true for temporal lobe epilepsy and hippocampal sclerosis [29, 64, 66–68, 80, 82, 83].

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CT Appearance of Pulmonary Tuberculosis in Diabetic and Immunocompromised Patients: Comparison with Patients Who Had No Underlying Disease

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OBJECTIVE. It has been stated, but not adequately assessed, that pulmonary tuberculosis in diabetic or immunocompromised patients often has an atypical pattern and distribution. To evaluate the CT features of pulmonary tuberculosis in diabetic or immunocompromised patients compared with patients without underlying disease, we performed this retrospective study.

MATERIALS AND METHODS. We reviewed conventional CT scans ($n = 110$) and high-resolution CT scans ($n = 16$) of the chest in 110 adult patients with active postprimary tuberculosis. Seventy-one patients had no underlying disease, 31 had diabetes mellitus, and eight were immunocompromised.

RESULTS. In patients who had no underlying disease, 44 had nodular opacities, 11 had consolidation, and 13 had consolidation with associated loss of volume. Characteristic features of tuberculosis in this group of patients included segmental distribution (97%), satellite lesions (93%), single cavity within any given lesion (95%), and tendency toward architectural distortion and loss of volume. In diabetic and immunocompromised patients, 15 had nodular opacities, seven had consolidation, and 15 had consolidation with associated loss of volume. Diabetic and immunocompromised patients had a high prevalence of nonsegmental distribution (30%) and multiple small cavities within any given lesion (44%). Unusual localization of tuberculosis, including disease confined to the basal segments of the lower lobes, anterior segment of the upper lobes, or right middle lobe, occurred equally in both groups (17% and 18%).

CONCLUSION. We conclude that diabetic and immunocompromised patients have a higher prevalence of multiple cavities within any given lesion ($p < .01$) and of nonsegmental distribution ($p < .01$) than do patients without underlying disease.

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The most common form of pulmonary tuberculosis in adults is postprimary or reinfection tuberculosis. Postprimary tuberculosis most commonly involves the apical and posterior segments of the upper lobes and the superior segments of the lower lobes [1-4]. It has been suggested that pulmonary tuberculosis in diabetic or immunocompromised patients often has an atypical pattern and distribution [2, 5, 6]. This has been confirmed, particularly in patients with AIDS, but has not been adequately assessed in patients who have diabetes or are immunocompromised [7-10].

We analyzed the spectrum of CT findings in patients with active pulmonary tuberculosis, paying special attention to differences in the pattern and distribution of findings in diabetic or immunocompromised patients as compared with those in patients without underlying diseases.

Materials and Methods

This study included 110 consecutive adults with newly diagnosed active postprimary pulmonary tuberculosis who had not been treated for current disease and who were admitted

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to a university hospital or a center for chest diseases. Seventy-one had no underlying disease, 31 had diabetes, and eight were immunocompromised (six had malignant tumors and two had been on long-term corticosteroid treatment). The patients included 88 men and 22 women 20 to 88 years old (mean, 52 years). In 87, the diagnosis was based on demonstration of *Mycobacterium tuberculosis* either by culturing or microscopic examination of sputum or material obtained by bronchoscopy. In the remaining 23, the diagnosis was based on clinical findings, in particular, characteristic radiologic findings and good response to treatment. All 110 patients were thought to have postprimary tuberculosis because they met the following criteria: (1) evidence of previous primary infection with tuberculosis, as shown by a documented positive reaction to skin testing with purified protein derivative (PPD) before the episode of current disease; (2) radiologic evidence of the previous primary infection; and/or (3) a previous positive culture for *Mycobacterium tuberculosis* without antituberculous treatment before the time of diagnosis of postprimary infection.

Chest radiographs, clinical records, and CT scans were available for all 110 patients. CT scans were obtained with a Toshiba 70A system, a GE 9800 system, or a Yokogawa Quantex system; 10-mm collimation and 10-mm intervals were used. High-resolution CT scans were obtained in 16 patients; 1.5- to 2-mm collimation and 2- to 2.5-cm intervals with a bone algorithm reconstruction were used.

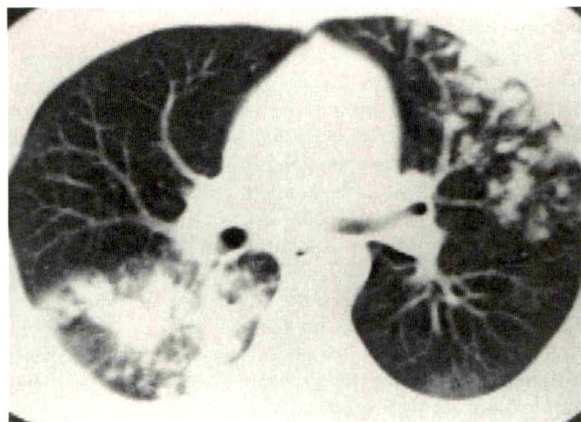
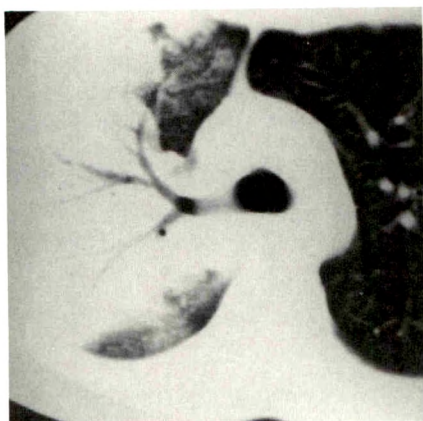
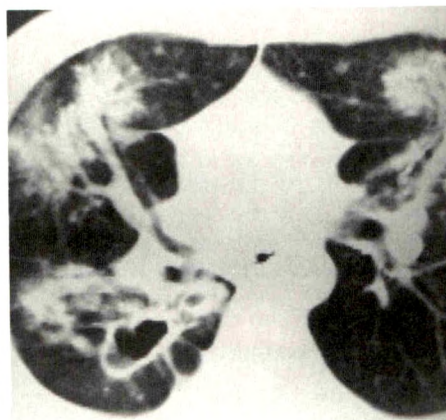


Fig. 1.—20-year-old woman with postprimary tuberculosis and no underlying disease. CT scan shows multiple nodular lesions of various sizes in superior segment of right lower lobe and anterior segment of left upper lobe (multiple segmental).



2



3

Fig. 2.—25-year-old man with postprimary tuberculosis and no underlying disease. CT scan shows confluent consolidation with air bronchogram. Nodules and ground-glass shadows are seen as satellite lesions in right upper and lower lobes.

Fig. 3.—56-year-old man with postprimary tuberculosis and no underlying disease. CT scan shows multiple areas of consolidation with associated loss of volume. Segmental distribution is clearly visible.

Retrospective analysis was performed by three independent chest radiologists as follows: (1) analysis of CT findings in patients with no underlying disease, (2) analysis of CT findings in diabetic or immunocompromised patients, (3) comparison of CT findings in diabetic or immunocompromised patients with those in patients without underlying disease. All abnormal findings including lymphadenopathy and pleural effusion were assessed. When a discrepancy occurred (3% of all findings), the final decision was reached by consensus. When the lesions extended to one or more segments of the lung, that is, the lesions were thought to have spread bronchogenically, we diagnosed segmental distribution.

The prevalences of nonsegmental distribution and multiple small cavities within any given lesion in patients with no underlying disease and in diabetic or immunocompromised patients were compared by means of a χ^2 -test.

Results

CT Findings in Patients Without Underlying Disease

The CT findings in the 71 patients without underlying disease could be classified into three main patterns: (1) nodular opacities, which included acinar, lobular, or patchy lesions, and nodular lesions of various sizes (Fig. 1); (2) confluent consolidation, often containing an air bronchogram (Fig. 2); and (3) consolidation with associated loss of volume (CWALV), often with air bronchogram (Fig. 3, Table 1). Forty-four (62%) of the 71 had a nodular pattern, 11 (15%) had confluent consolidation, and 13 (81%) had CWALV. In the 44 with the nodular pattern, 12 (27%) had a relatively large nodular lesion with or without satellite lesions; the remaining 32 (73%) had multiple nodular lesions (Fig. 1). Thirteen of the 44 had cavitory lesions and 42 of the 44 had satellite lesions. In the 11 with confluent consolidation, nine had segmental distribution, eight had air bronchograms (Fig. 2), and three had cavitory lesions. Satellite lesions were found in 10 patients (91%), manifesting as small nodular lesions or as ground-glass shadows or areas with slightly increased density (Fig. 2). Air bronchograms found in confluent consolidation often showed ectatic bronchi. All 13 patients with CWALV had segmental distribution, six had air bronchograms, and six had cavitory lesions. Satellite lesions were found in 11 (85%). A tendency toward distortion or contraction was observed in all the patients who had CWALV and in 28 of the 44 who had nodular lesions.

TABLE 1: CT Findings in Postprimary Pulmonary Tuberculosis in Adults

CT Pattern and Findings	No. (%) of Patients with No Underlying Disease (n = 71)	No. (%) of Diabetic or Immunocompromised Patients (n = 39)
Pattern		
Nodular opacities	44 (62)	15 (38)
Confluent consolidation	11 (15)	7 (18)
Consolidation with associated loss of volume	13 (18)	15 (38)
Miliary tuberculosis	3 (4)	2 (5)
Findings		
Unusual localization	12 (17)	7 (18)
Nonsegmental distribution ^a	2 (3)	11 (28)
Lymph node enlargement	9 (13)	8 (21)
Cavities within any given lesion	22 (31)	18 (46)
Single cavity	21 (95)	10 (56)
Multiple cavities ^a	1 (5)	8 (44)

^a Difference between the two groups of patients was statistically significant ($p < .01$).

The other CT patterns observed in these patients included miliary tuberculosis in three (4%). In these three, conventional CT scans showed small nodular lesions diffusely disseminated in both lungs.

Unusual localization of tuberculosis was found in 12 of the 71 patients with no underlying disease (Fig. 4). In these 12, the lesions were confined either to the basal segment of the lower lobe (five), the anterior segment of the upper lobe (five), or the right middle lobe (two).

Except for those with miliary tuberculosis, almost all patients (66/68, 97%) had segmental distribution. The lesions were confined to a single segment in 21 patients; they occupied multiple segments of a single lung in 21 and multiple segments of both lungs in 24.

Twenty-two of the 71 had cavitory lesions. Thirteen had a nodular pattern, three had confluent consolidation, and six had CWALV. Lesions could be single or multiple, but for all cavitory lesions except one, a given lesion that cavitated contained only a single cavity; in the one exception, multiple small cavities were found within a single confluent consolidation. Satellite lesions, such as small nodular lesions or slightly increased attenuation surrounding the main lesion, were found in 63 (93%) of 68 patients who had the main CT patterns of parenchymal abnormalities (42 of 44 nodular lesions, 10 of 11 confluent consolidations, and 11 of 13 CWALV).

CT Findings in Diabetic or Immunocompromised Patients

The CT patterns seen in diabetic and immunocompromised patients were essentially similar to those seen in patients without underlying diseases. However, the prevalence of the nodular pattern was low (38%) and that of CWALV was high (38%) compared with those in patients who had no underlying disease. Miliary tuberculosis was found in two patients (5%).

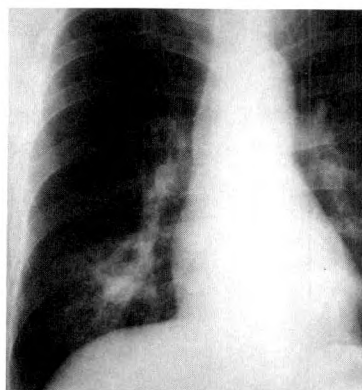
Nonsegmental distribution of disease was observed in 11 patients (28%; Fig. 5). Eighteen of the 39 diabetic or immunocompromised patients had cavitory lesions, and eight (44%) of these 18 had multiple small cavities in any given lesion (Figs. 6 and 7). Three were in confluent consolidations, and five were seen in CWALV. These cavities had irregular shapes and often had small protrusions (Figs. 6 and 7). A peripheral bronchiole connecting to the cavity was clearly seen in some cases (Fig. 7). Unusual localization of disease was observed in seven (18%) of the 39. The lesions were confined to the basal segment of the lower lobe in two, the middle lobe or lingula in three, and the anterior segment of the upper lobe in two. Compared with patients with pulmonary tuberculosis and no underlying disease, diabetic and immunocompromised patients had a higher prevalence of nonsegmental distribution ($p < .01$) and multiple cavities in any given lesion ($p < .01$).

High-resolution CT scans were obtained in 16 patients with nodular disease (10 with underlying disease and six without

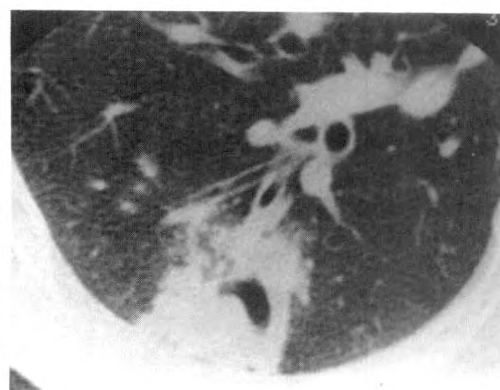
Fig. 4.—Tuberculosis of lower lung zone in a 44-year-old man with diabetes mellitus.

A. Chest radiograph shows consolidation in right lower lobe.

B. High-resolution CT scan shows cavitory nodule exclusively in lateral basal segment of right lower lobe.



A



B

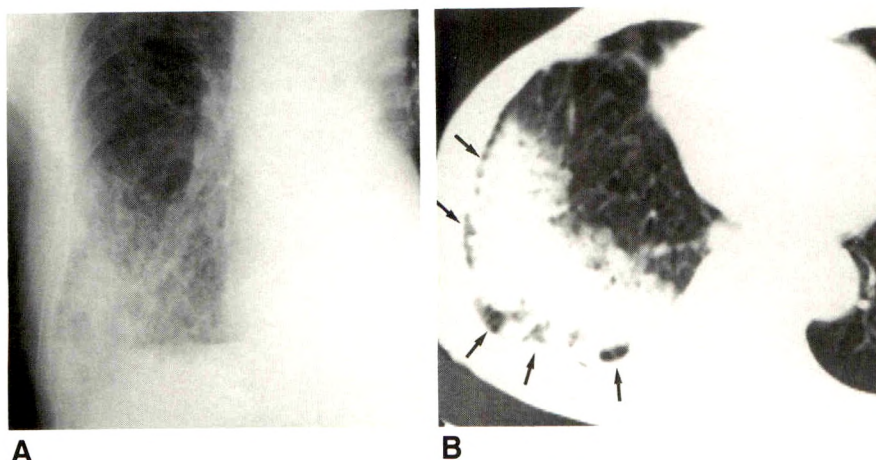


Fig. 5.—Nonsegmental distribution of postprimary tuberculosis in a 77-year-old man with diabetes mellitus.

A, Chest radiograph shows inhomogeneous consolidation in right lower lobe of lung.

B, CT scan clearly shows that confluent consolidation is nonsegmental. Note bullous or emphysematous changes (arrows) in peripheral lung parenchyma.

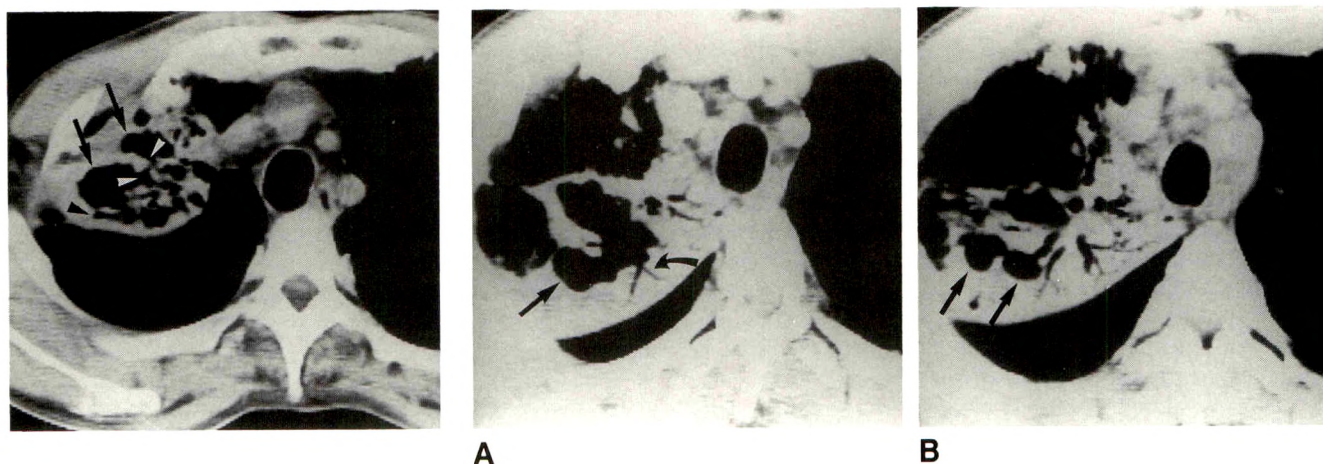


Fig. 6.—Postprimary tuberculosis in a 48-year-old woman with diabetes mellitus. CT scan shows multiple small cavities (arrows) in a single confluent consolidation in lung. Cavities are not round and have small protrusions (arrowheads).

Fig. 7.—Postprimary tuberculosis in a 41-year-old man with diabetes mellitus. A and B, CT scans show multiple small cavities (straight arrows) in a single confluent consolidation of right upper lobe of lung. Peripheral bronchiole connecting to cavity is clearly visible (curved arrow).

underlying disease). Poorly defined small nodules or regions with slightly increased attenuation on conventional CT scans were shown on high-resolution CT scans to be aggregations of well-defined small nodules or small irregular opacities in all 16 patients.

Discussion

Impaired host immunity has been regarded as a predisposing factor in postprimary tuberculosis in adults. Classically, tuberculosis reportedly occurs more commonly during old age; in persons who have diabetes, renal failure, malignant neoplasms, or alcoholism; and in persons who are receiving corticosteroid treatment [2, 11–13]. More recently, the association has been broadened to include AIDS [7–10]. Whether these associations also foster the development of unusual radiologic features is not entirely clear.

The characteristic radiologic features of tuberculosis in patients with AIDS is lymphadenopathy and diffuse inhomogeneous parenchymal opacities. Cavitory disease is rare in

these patients. It has been thought that the type of abnormalities depends on the immune status of the patients at the time tuberculosis becomes evident. Thus, in the early course of HIV infection, when immunosuppression is minimal, tuberculosis may mimic typical postprimary disease seen in nonimmunocompromised hosts [8].

In cases of pulmonary tuberculosis in patients who are immunocompromised as the result of corticosteroid therapy or hematologic or solid neoplasms, clinical and radiologic findings are similar to those of postprimary tuberculosis in nonimmunocompromised hosts [14]. On the other hand, in patients who have coexisting pulmonary tuberculosis and diabetes, pulmonary tuberculosis at the unusual site has been stressed [2, 5, 6, 15, 16]. In patients with diabetes, the prevalence of tuberculosis in the lower lung zone and the anterior segments of the upper lobe reportedly is higher than that in nondiabetic patients [5, 6, 15, 16].

In our study, the following CT findings of active tuberculosis were found in adults without underlying diseases: Whether the lesions were single or multiple, they were segmentally

distributed (97%). Satellite lesions were found in 93% of patients. Some degree of distortion or contraction was observed in CWALV and in nodular lesions. Cavitation occurred in 31% of cases, and except in one case, the cavities within a given lesion were single, although these patients may have more than one lesion and therefore more than one cavity. In 17% of the cases, the abnormality was limited to the basal segments of the lower lobe or the anterior segment of the upper lobe or middle lobe. Except for unusual localization of the lesions, the characteristic CT findings in this group of patients were the same as previously reported [17, 18].

In diabetic or immunocompromised patients with active tuberculosis, the following features were frequently found: multiplicity of small cavities within a single consolidative focus (eight of 18 cavitary lesions) and nonsegmental distribution of lesions (11 of 39 patients). In diabetic patients, unusual localizations—such as lesions confined to the basal segments of the lower lobe, the anterior segment of the upper lobe, and the medial and lateral segments of the middle lobe—were often reported [2, 5, 6, 15, 16]. In our series, unusual localization of the lesion was found in 12 (17%) of 71 patients who had no underlying disease and in seven (18%) of 39 patients who were diabetic or immunocompromised. Furthermore, tuberculosis in the lower lung zone, which included disease in the basal segments of the lower lobes and in the right middle lobe and lingula, occurred in eight (11%) of 71 cases and five (13%) of 39, respectively. The prevalence of disease in the lower lung zone reported previously ranged from 5% to 20% [2, 5–7, 15, 16]. Diabetes mellitus was thought to be the only significant condition to predispose disease of the lower lung zone, but we found no difference in that feature between diabetic patients and patients without underlying diseases in our series.

In diabetic or immunocompromised patients with pulmonary tuberculosis, a high prevalence of multiple small cavities within any given lesion and nonsegmental distribution were observed. No reports describing similar radiologic features have been published. One of the reasons is that we used CT scans, and most of the previous studies used chest radiographs. Compared with radiographs, CT scans provide more precise information about the extent and distribution of disease, the presence of satellite lesions, and the presence and nature of the cavities [17, 18]. The multiple cavities observed in diabetic or immunocompromised patients are thought to be different from the usual type of cavity seen in pulmonary tuberculosis and the cystic bronchiectasis seen as a chronic change in tuberculosis. These cavities within consolidation were not round and often had small protrusions. In some cases, a peripheral bronchiole connecting to the cavity was clearly seen (Fig. 7A). The typical cavity in tuberculosis originates in the acinar region (i.e., in the most peripheral region of the lung parenchyma), and thus more peripheral bronchioles connected to the cavity and small protrusions of the cavity are never seen. Furthermore, these findings are never seen in cystic bronchiectasis either. Surrounding consolidation is not necessary for cystic bronchiectasis. Cystic bronchiectasis is one of the chronic changes of pulmonary tuberculosis, but the regions of consolidation containing multiple cavitary le-

sions in our series were relatively clear before the current episode of disease. The pathogenesis and pathologic features of this type of cavity have been described by Iwasaki [19]. The mucosa of the bronchus or bronchiole is repeatedly exposed to *Mycobacterium tuberculosis*, resulting in caseous bronchitis. When this caseous material is eliminated, an ulcer forms on the bronchial wall. When the ulcer is deep, areas of inflammation directly penetrate the surrounding lung parenchyma, resulting in a bronchiectatic cavity, which is not true bronchiectasis but a cavity. This type of cavity often connects with normal, more peripheral bronchioles.

In conclusion, CT findings of active tuberculosis in diabetic or immunocompromised adult patients differ from those in patients without underlying disease. Diabetic or immunocompromised patients with tuberculosis have a higher prevalence of nonsegmental distribution and of multiplicity of small cavities within a tuberculous lesion than do patients without underlying disease.

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Food for thought. . .

Happy Holidays

To All Our
Readers, Authors, and Reviewers
From the AJR
Editorial Staff

Pictorial Essay

CT of Fatty Thoracic Masses

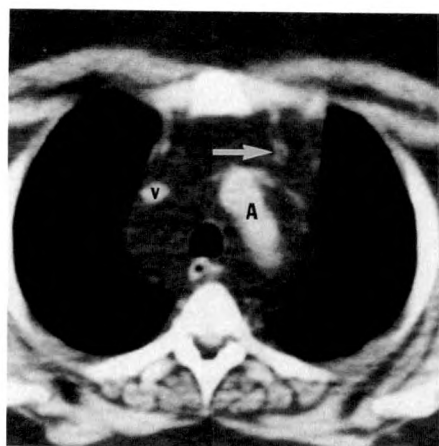
Harvey S. Glazer,¹ Mark R. Wick,² Dixie J. Anderson,¹ Janice W. Semenkovich,¹ Paul L. Molina,¹ Marilyn J. Siegel,¹ and Stuart S. Sagel¹

A variety of masses within the mediastinum, lung, pleura, or chest wall may contain areas of fat attenuation. In some cases, the mass is entirely fat (e.g., mediastinal lipomatosis), whereas in others, fat is only one component of the lesion (e.g., teratoma). In this report, the gamut of fatty thoracic masses that can be seen on CT is illustrated.

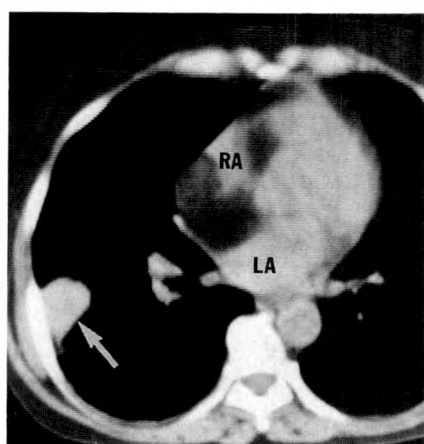
Mediastinum

Mediastinal Lipomatosis

Mediastinal lipomatosis is a benign entity in which increased collections of unencapsulated, histologically normal fat are present in the mediastinum. It is most commonly seen with



A



B

Fig. 1.—Mediastinal lipomatosis.

A, CT scan shows abundant fat throughout superior mediastinum. Fat is homogeneous and similar in attenuation to subcutaneous fat. Arrow = residual thymic tissue or mediastinal lymph node, v = right innominate vein, A = aortic arch.

B, In a different patient, CT scan shows lipomatous hypertrophy of interatrial septum. RA = right atrium, LA = left atrium, arrow = bronchogenic carcinoma.

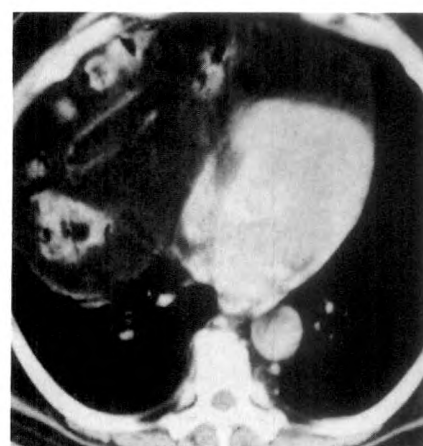


Fig. 2.—Morgagni's hernia. CT scan at level of heart shows a large Morgagni's hernia containing large bowel and omental fat. Focal eventration of diaphragm can be differentiated from a Morgagni's hernia by the intact diaphragm in the former entity.

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obesity, administration of corticosteroids, or Cushing's syndrome. However, in some cases, no such predisposing factors are present. The fat accumulates most commonly in the upper anterior mediastinum but also may be seen in the cardiophrenic angles (pericardial fat pads), paraspinal areas, or even in the interatrial or atrioventricular grooves (Fig. 1). Associated extrapleural fat also may be present. Usually no compression of adjacent structures occurs. The fat is homogeneous and similar in attenuation to subcutaneous fat (-80 to -120 H). If the fat is inhomogeneous, other causes, such as neoplastic infiltration, mediastinitis, or prior surgery or irradiation need to be considered. Small foci of residual thymic tissue in the anterior mediastinum, however, should not be interpreted as representing infiltrated fat.

Herniation of Abdominal Fat

A hernia through the foramen of Morgagni usually occurs in the right cardiophrenic angle and commonly contains omen-

tal fat (Fig. 2). Detection of fine linear opacities within the fat, representing the omental vessels, may be helpful in distinguishing this entity from a pericardial fat pad. Omental fat also can extend into the mediastinum through the esophageal hiatus (Fig. 3). Fat herniation through the foramen of Bochdalek or through acquired diaphragmatic defects is more commonly seen posteriorly in the left hemithorax than in the right hemithorax (Fig. 4).

Neoplasms

Lipomas are uncommon mediastinal tumors that may be seen in any part of the mediastinum. They are well defined, may be encapsulated, and usually do not compress adjacent structures unless they are large (Figs. 5 and 6). Although generally homogeneous, lipomas may contain thin fibrous septa. If the mass is inhomogeneous, contains areas of soft-tissue attenuation, or is poorly defined, an alternative diagnosis should be considered (e.g., liposarcoma; Fig. 7).

Benign mature teratomas are the most common mediastinal

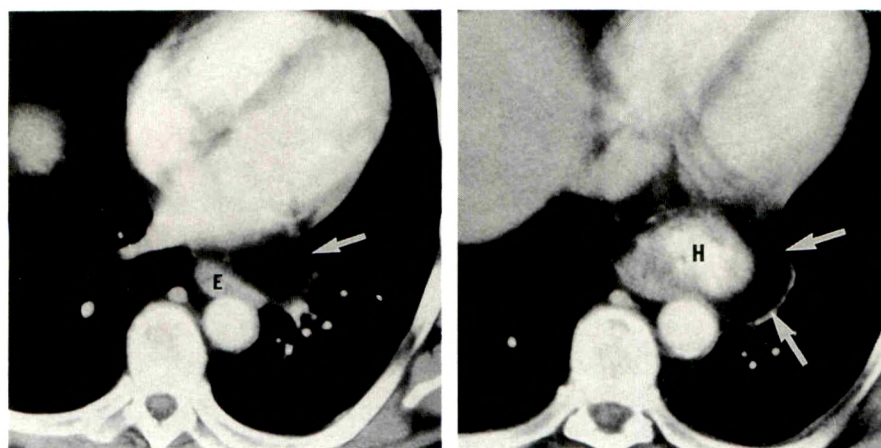


Fig. 3.—Hiatal hernia.
A and B, CT scans show herniation of omentum (arrows) in association with a hiatal hernia (H). E = esophagus.

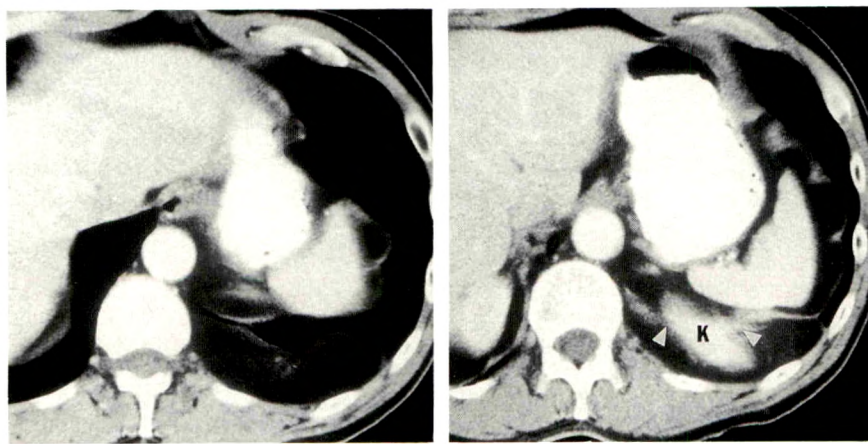


Fig. 4.—Bochdalek's hernia.
A and B, CT scans show intraabdominal fat and top of left kidney (K) extending through a posterior defect (arrowheads) in left hemidiaphragm.

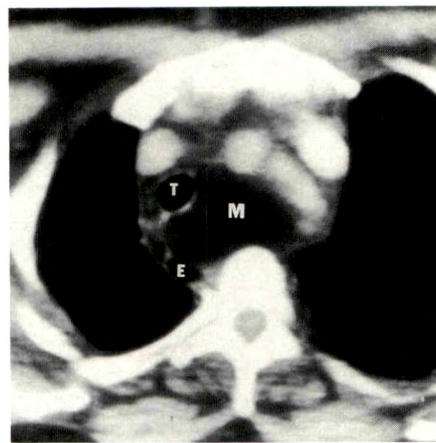


Fig. 5.—Mediastinal lipoma. CT scan shows homogeneous fatty mass (M) displacing trachea (T) and esophagus (E) laterally. (Case courtesy of A. Hammerman, St. Louis, MO.)

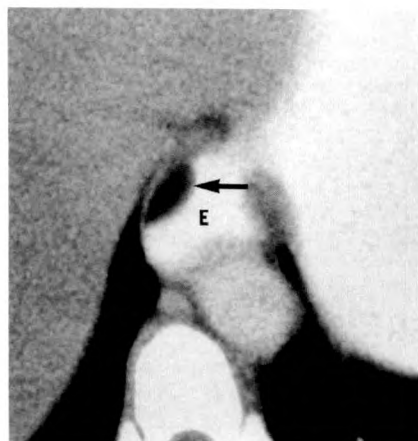


Fig. 6.—Esophageal lipoma. CT scan shows homogeneous fatty mass (arrow) in right lateral wall of barium-filled esophagus (E). A submucosal mass was seen on a prior upper gastrointestinal examination.

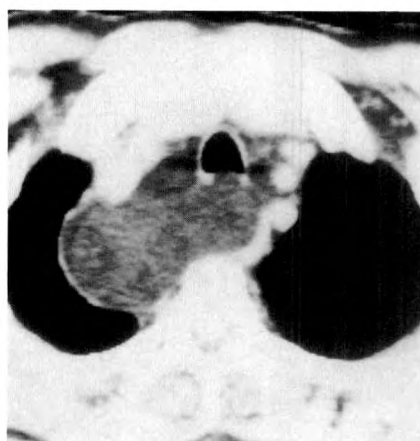


Fig. 7.—Liposarcoma. CT scan shows large, relatively inhomogeneous mass in right side of mediastinum. Note that mass has slightly higher attenuation than subcutaneous fat does. Mass extended into right side of neck to involve right recurrent laryngeal nerve, paralyzing right vocal cord. Although no biopsy was done, mass has shown progressive slow growth and presumably is a well-differentiated liposarcoma.

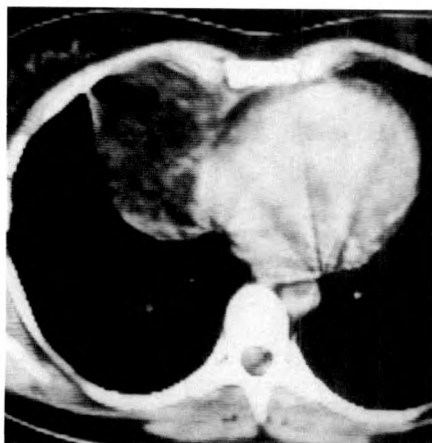


Fig. 8.—Benign mature teratoma. CT scan shows a large, complex mass containing fat, multiple cysts, and calcification (arrow).

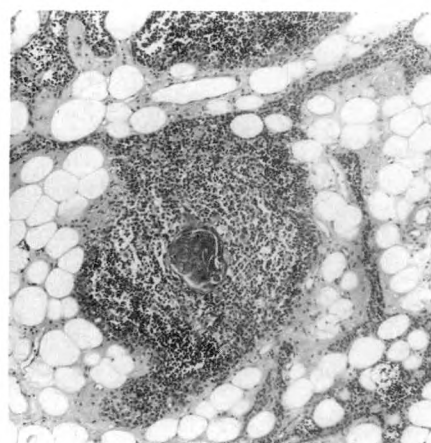
Fig. 9.—Thymolipoma.

A, CT scan shows a large, predominantly fatty mass adjacent to right side of heart. Scattered areas of soft-tissue attenuation are seen within mass. More cephalad scans showed extension to level of aortic arch. (Case courtesy of D. Sloan, Herrin, IL.)

B, Photomicrograph of histologic section shows a lobule of normal thymic tissue with a Hassall's corpuscle surrounded by mature adipose tissue.



A



B

germ cell tumor and are usually located within the thymus; rarely, however, these lesions can arise in the posterior mediastinum as well. On CT scans, the admixture of fat, fluid, soft tissue, and calcification suggests the diagnosis, although fat is present in 50% or fewer of cases (Fig. 8). Rarely a fat-fluid level may be seen. Malignant germ cell tumors are mostly soft tissue and usually have poorly defined borders.

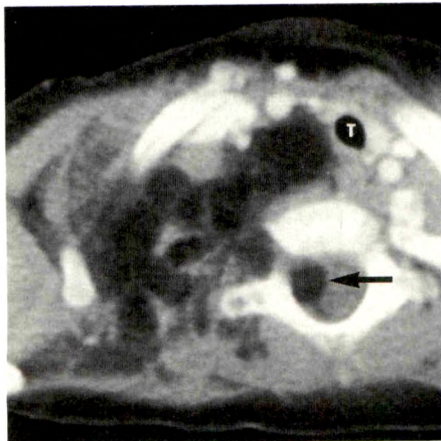
Thymolipomas are composed of mature thymic lobules and fat. Islands of soft-tissue attenuation seen on CT scans are attributable to the presence of admixed thymic tissue and fibrotic stroma (Fig. 9). These lesions are usually seen in children and young adults and usually are quite large.

Lipoblastomas, which occur almost always in infants and young children, are usually seen in the extremities or trunk and only rarely involve the mediastinum (Fig. 10). They contain

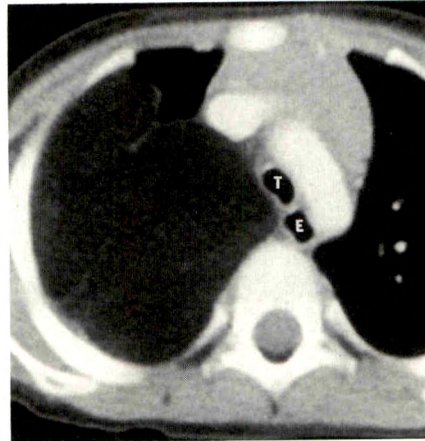
lobules of immature adipose tissue separated by fibrous septa.

Miscellaneous Fatty Mediastinal Masses

Extravasation of lipid-rich hyperalimentation fluid is a rare cause of a fatty mediastinal mass [1]. Adipocytic metaplasia in extramedullary hematopoiesis has been described and is a consequence in some cases of resolution of the causative hemolytic disorders [2] (Fig. 11). Central fibrofatty replacement of mediastinal lymph nodes can normally occur as a result of previous reactive inflammatory disease (Fig. 12); more diffuse low-attenuation nodes have been reported in Whipple's disease [3].

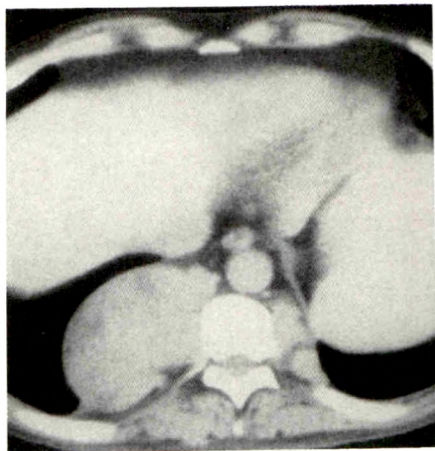


A

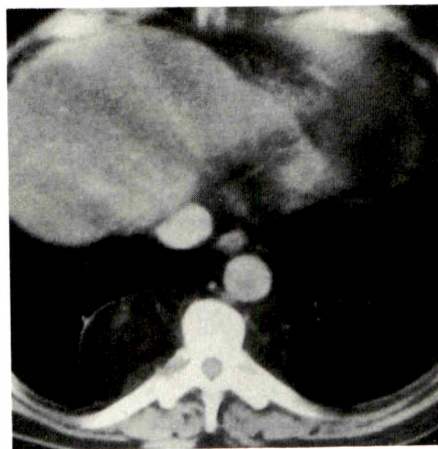


B

Fig. 10.—Lipoblastoma. A and B, CT scans show a large multiseptated fatty mass that infiltrates right side of neck, displaces trachea (T) and esophagus (E), and extends into spinal canal (arrow). (Case courtesy of J. P. Kuhn, Buffalo, NY.)



A



B

Fig. 11.—Extramedullary hematopoiesis associated with hereditary spherocytosis.

A, CT scan through lower thorax shows bilateral paraspinal masses with soft-tissue attenuation.

B, CT scan obtained 5 years after splenectomy shows that masses now have attenuation of fat. Diffuse fatty infiltration of liver also has occurred.

(Reprinted with permission from Martin et al. [2].)



Fig. 12.—Fibrofatty replacement of mediastinal lymph node. CT scan of 2-mm-thick section shows fat (arrow) within a 1-cm pretracheal lymph node.

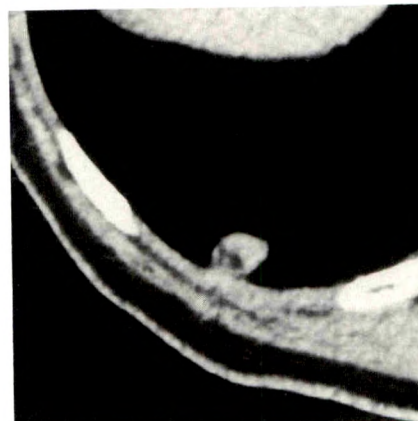


Fig. 13.—Hamartoma. CT scan of 2-mm-thick section shows a smooth 1-cm pulmonary nodule containing fat.

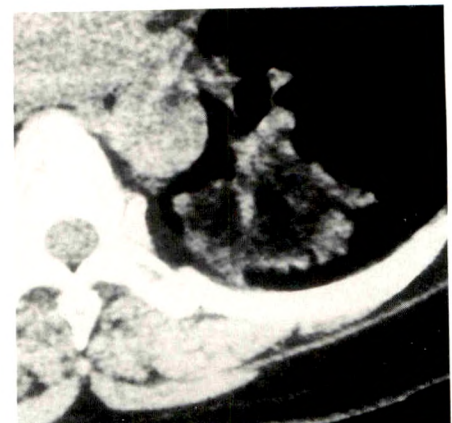


Fig. 14.—Lipoid pneumonia. CT scan at level of superior segment of left lower lobe of lung shows a predominantly fatty attenuation area of lung consolidation. Similar findings were seen in superior segment of right lower lobe and in right middle lobe. Subsequently, patient related a 20-year history of placing olive oil in her nostrils at night to prevent colds.

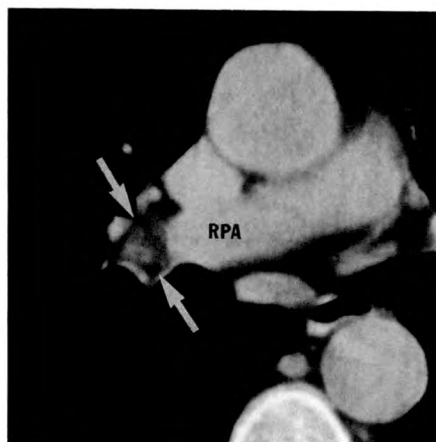


Fig. 15.—Prominent fat collection in hilum of right lung. CT scan at level of right pulmonary artery (RPA) shows a 1.5-cm mass (arrows) that is caused by fat and a few small lymph nodes.

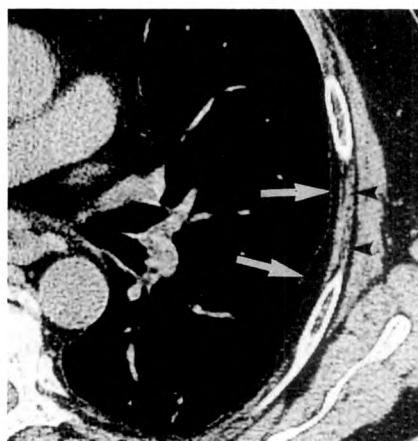


Fig. 16.—Abundant extrapleural fat. CT scan of 2-mm-thick section shows abundant extrapleural fat (arrows). Extrapleural fat is frequently misinterpreted as "pleural thickening" on chest radiographs. Arrowheads = intercostal muscles.

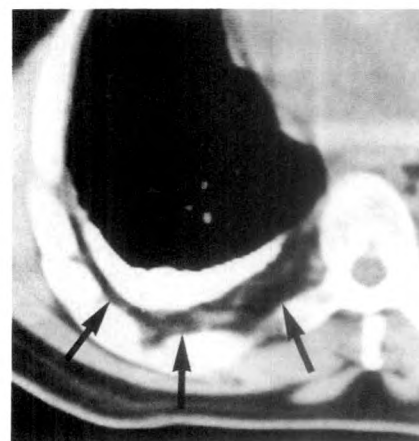


Fig. 17.—Old tuberculous empyema. CT scan shows abundant extrapleural fat (arrows) underlying an old calcified tuberculous empyema.

Lung

Neoplasm

Hamartomas account for about 7% of all resected pulmonary nodules. The CT finding that is suggestive of this lesion is a smooth pulmonary nodule 2.5 cm or less in diameter that contains focal collections of fat or fat alternating with areas of calcification [4] (Fig. 13). Thin-section images (2 mm or less) may be necessary to show fat within the nodule. Conservative follow-up is recommended for lesions that satisfy the CT criteria for hamartoma.

Endobronchial hamartomas are less common and are often symptomatic, in contrast to the pulmonary ones. Lipomas are another rare endobronchial fatty neoplasm.

Lipoid Pneumonia

Areas of fatty attenuation within a pulmonary infiltrate are diagnostic of lipoid pneumonia (Fig. 14). Areas of higher attenuation also may be seen as a result of associated inflammation.

Hilar Fat Collections

Normal collections of fat and lymph nodes can be seen in both hila (Fig. 15). Awareness of this normal finding will help avoid confusion with lymphadenopathy. The fatty component may be more apparent on thin-section images.

Pleura and Chest Wall

Extrapleural Fat

Collections of extrapleural fat normally may be seen on CT scans, especially on thin-section scans (Fig. 16). This adipose

tissue, which is located between the parietal pleura and endothoracic fascia, is most commonly seen over the posterolateral aspect of the fourth to eighth ribs. Extrapleural collections are larger in patients who are obese or are taking corticosteroids. Fat in the extrapleural space also is commonly thicker adjacent to areas of chronic pleural disease (Fig. 17). The apical cap seen in patients who have had pulmonary tuberculosis results primarily from thickening of the extrapleural fat in this location [5] (Fig. 18). Extrapleural fat may be displaced medially as a result of extrapleural tumor, edema, or hemorrhage [6].

Intrafissural Fat

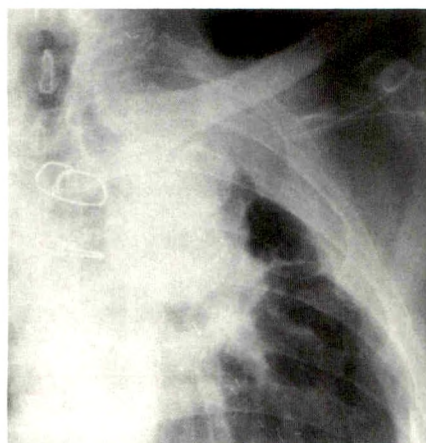
Small collections of fat can occasionally be seen within the major pulmonary fissures, representing extensions of extrapleural or mediastinal fat (Fig. 19). These collections are most commonly present in the caudal aspect of the major fissure.

Lipomatosis

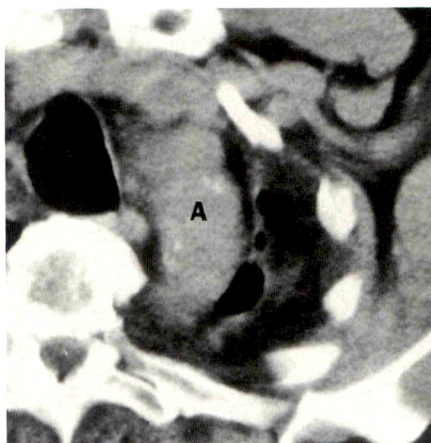
Excessive accumulation of subcutaneous fat is usually caused by obesity or corticosteroids. Lipomatosis can be seen in association with collections of fat within the mediastinum or extrapleural space. Diffuse lipomatosis is a rare condition in which an overgrowth of mature fat (without nuclear atypia) infiltrates the muscles of an extremity or, less commonly, the trunk [7].

Neoplasm

Extrapleural or chest wall lipomas resemble mediastinal lipomas, appearing as well-defined fatty masses (Fig. 20). In some cases the lipoma is transmural, with both intrathoracic and extrathoracic components. Although a well-differentiated



A



B

Fig. 18.—Apical opacity.

A, Posteroanterior chest radiograph in patient with history of tuberculosis shows extensive left apical capping with associated volume loss in left upper lobe. Sternotomy and surgical clips are from a prior coronary artery bypass procedure.

B, CT scan at level of top of aortic arch (A) shows that capping is caused by extrapleural fat.

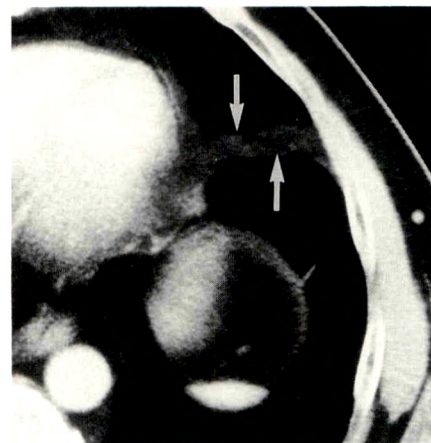
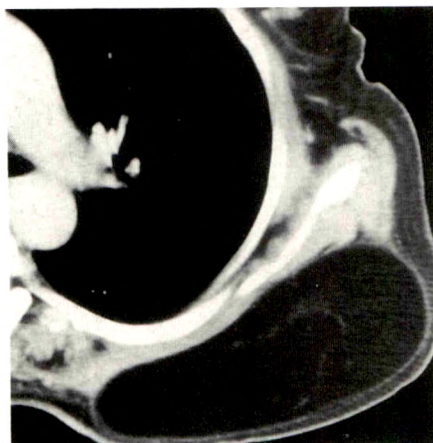
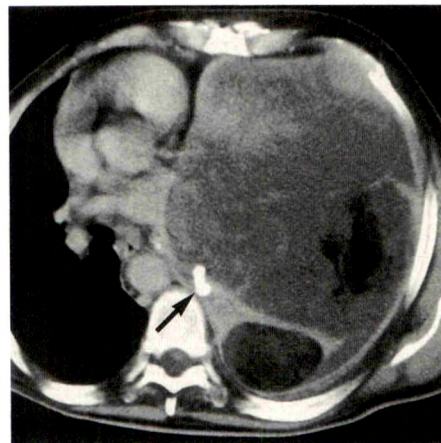


Fig. 19.—Intrafissural fat. CT scan near top of left hemidiaphragm shows a large band of fat (arrows) in base of left major fissure.



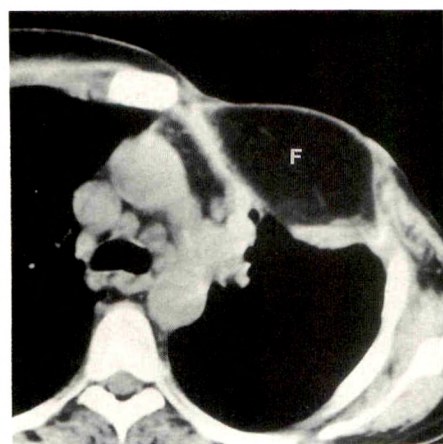
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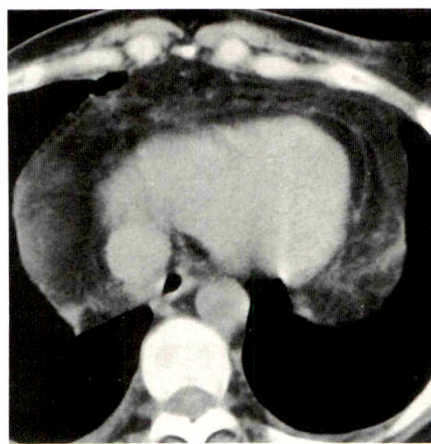
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Fig. 20.—Chest wall lipoma. CT scan shows a large relatively homogeneous mass posterior to left scapula. Linear opacities within mass presumably represent fibrous septa.

Fig. 21.—Metastatic liposarcoma. CT scan shows a large complex mass in left hemithorax that contains fat, fluid, and soft tissue. Patient had previously had a liposarcoma in his lower extremity resected. Arrow = calcified lymph node from prior healed granulomatous disease.



A



B

Fig. 22.—Surgical flaps.

A, CT scan shows a mostly fat-attenuation myocutaneous flap (F) in anterior aspect of left hemithorax. Enlarged mediastinal lymph nodes also are seen. Patient had prior mastectomy of left breast and resection of chest wall.

B, CT scan in a patient who had prior bilateral lung transplantation with bronchial omentopexy shows two pedicles of omental flap extending around heart.

liposarcoma may be indistinguishable from a lipoma, in most cases of the former, areas of soft-tissue attenuation are present (Fig. 21).

Surgical Flaps

Myocutaneous flaps have been used to repair chest wall defects. Fatty replacement of the muscular portion of such a flap can be seen as a mostly fatty mass on CT scans (Fig. 22A). Intrapleural components of the omental flaps used to wrap the bronchial anastomoses in lung transplantations are most frequently seen in the paraspinal region or cardiophrenic angles (Fig. 22B).

Miscellaneous

Elastofibromas are benign lesions thought to be caused by reactive hyperplasia from mechanical stimulation. They are usually located in the subscapular area and contain a mixture of collagen, fibroblasts, and mature fat. The mass is unencap-

sulated, so on CT scans it may mimic an infiltrating malignant neoplasm (e.g., liposarcoma) [8].

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Book Review

Nonpalpable Breast Cancer. Diagnosis and Management. By George Hermann, Ira S. Schwartz, and Paul I. Tartter. New York: Igaku-Shoin, 132 pp., 1992. \$59.50

This concise 132-page book about nonpalpable breast cancer contains eight chapters. Topics covered include data from screening programs, an overview of breast imaging techniques, radiologic-pathologic correlation of nonpalpable breast lesions, localization techniques, the role of the pathologist, management of nonpalpable breast cancer, prognosis, and controversies. The team effort necessary for the diagnosis and management of breast cancer is reflected by the fact that the authors come from the disciplines of radiology, pathology, and surgery.

The book begins with a comprehensive review of major screening studies dealing with mammographic detection of breast cancer. The chapter on controversies is quite interesting. In it, such diverse topics as a critical analysis of screening data, the costs of mammography, the age at which screening should begin, and optimal screening intervals are addressed. The longest chapter of the book is devoted to radiologic-pathologic correlation. This chapter deals with nonpalpable breast lesions in general and is not confined to cancer. Of the mammograms included, more than half show benign processes. Many entities are nicely correlated. The material could be enhanced by including more mammograms with better resolution of malignant microcalcifications. Many of the figures are not near the correspond-

ing text, so reading this chapter requires a great deal of page turning back and forth.

The book has some surprising omissions. The section on breast imaging techniques does not include a comparison of film-screen mammography vs xeroradiography. No discussion is included on inking the specimen and the important role the pathologist has in the critical evaluation of whether the tumor has been completely excised. Although breast conservation is discussed, the text does not cover the radiology of these patients, nor the signs of tumor recurrence in the treated breast.

This book can serve as an introductory text on the diagnosis and management of nonpalpable breast cancer. Someone who is beginning to learn about this area of medicine could benefit from this overview, but for any in-depth knowledge, other sources will be required.

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Technical Note

A Modified Technique for Breast Compression During Needle Localization

Barry F. Bates^{1,2} and Helen Gaskin¹

In several cases of breast biopsy with needle localization, we observed that a lesion clearly visible on the routine mammograms became difficult to see on radiographs taken for

localization (Fig. 1). In the biopsy compression plate, an area has been removed to allow placement of the localizing needle. During compression, breast tissue can be forced upward

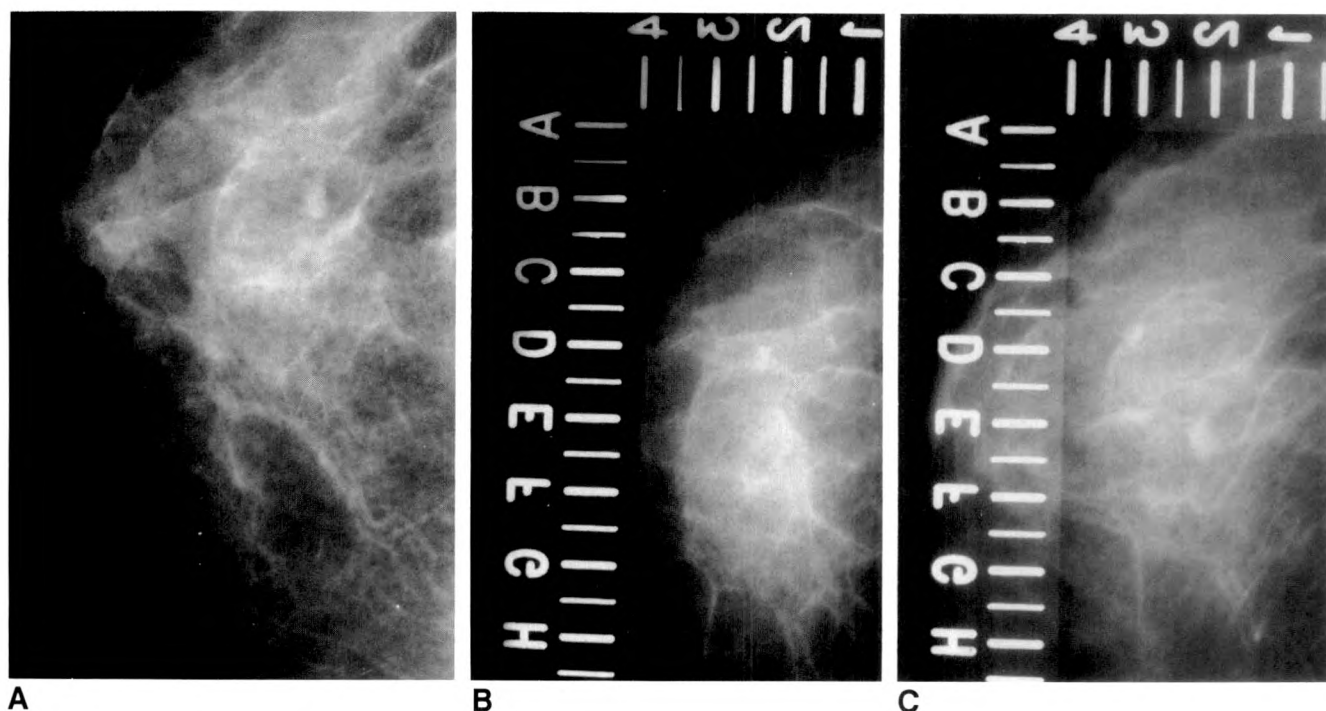


Fig. 1.—Asymptomatic woman with impalpable nodule discovered on screening mammogram.

A, Standard compression mammogram shows small nodule in center of breast.

B, On initial localization radiograph obtained without Incise Drape, center of breast is less well compressed than on A and nodule is not visualized.

C, On radiograph obtained with Incise Drape in place, nodule is now seen in center of breast. Biopsy showed fibroadenoma.

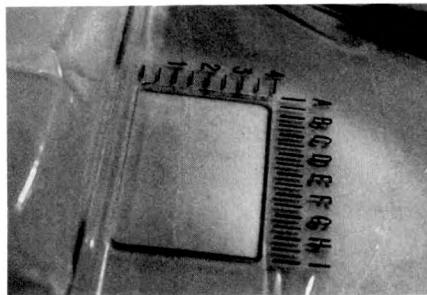
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2



3

Fig. 2.—Breast tissue bulges through opening in localization compression plate.

Fig. 3.—Compression of breast with Incise Drape in place. With same degree of compression as in Fig. 2, no bulging of breast tissue occurs.

through this opening. As a result, the area of the breast containing the finding of interest can be compressed less than the remainder of the breast is compressed (Fig. 2). This may account for the occasional poor visualization of lesions during localization. We present a modification of the compression technique that can be used during localization procedures to prevent this unequal compression.

Materials and Methods

A flexible plastic sheet (Barrier Incise Drape; Surgikos Inc., Arlington, TX) was placed over the opening in the compression plate. The drape is designed to cover skin around surgical incisions. It is sterilized and has adhesive on one side. The drape is placed, using sterile technique, on the underside of the localization compression plate with the adhesive side affixed to the compression plate. The drape is stretched taut so that it will compress the part of the breast that is beneath the opening of the compression plate. Once the drape is in place, the patient's skin is prepared with an iodine solution, and the compression plate is placed over the area of interest. Compression is applied in the usual fashion (Fig. 3), and the first localization radiograph is taken. The grid marking system in the mammography machine is used to determine the site for needle puncture. The needle is then placed through the drape into the breast. After the location of the needle tip is confirmed, the compression plate is withdrawn from the breast while the localization needle is supported and steadied. When the skin of the breast is separated from the plastic barrier sheet, a scalpel blade is used to cut the drape away from the needle. With care, movement of the drape is minimal and did not, in our experience, move the needle. The localization plate is removed and

replaced by the standard compression plate. The breast is then radiographed at a right angle to the original projection to show the depth of the needle tip. After final adjustment of the needle depth, the needle is withdrawn, and the localizing wire is left in place.

Discussion

Two cases illustrate the use of this technique. In the first one, a routine mammogram showed a small lesion in one breast (Fig. 1A). On a localization radiograph, the lesion was not shown clearly (Fig. 1B). After the Incise Drape was placed on the compression plate, the nodule was again clearly visible (Fig. 1C). Biopsy revealed a small fibroadenoma. In another case, routine mammograms showed a cluster of tiny calcifications. On the initial localization radiograph, only two flecks of calcium were seen. When the drape was in place, more flecks were seen, and those were more clearly visualized.

In most cases, addition of the drape is unnecessary. However, when the initial localization radiograph shows an area of interest less well than standard mammograms do, the addition of the drape may significantly improve visualization and make it easier to localize the lesion.

ACKNOWLEDGMENTS

We thank the staff of Chelsea Community Hospital for their assistance in preparing the photographs.

Perspective

Imaging of Patients with Potentially Resectable Hepatic Neoplasms

Roger K. Harned II,¹ Judith L. Chezmar, and Rendon C. Nelson

Curative surgery for hepatic metastases has become increasingly common in the past decade. This increase is due to a combination of factors, including the development of relatively bloodless ultrasonic surgical dissection techniques, parenchyma-sparing operative approaches, and earlier detection of metastatic lesions by such tests as serial serum assays for carcinoembryonic antigen. Occasional long-term survival has been reported after resection of hepatic metastases from melanoma, leiomyosarcoma, pancreatic cancer, gastric cancer, renal cell cancer, and adrenal carcinoma [1]. However, most of the published data concern surgical resection of hepatic metastases from colorectal carcinoma.

Of the approximately 157,500 persons in whom colorectal cancer is diagnosed each year, it is estimated that 5% will meet the criteria for hepatic resection. Follow-up has shown a 5-year survival rate of 20–30% in patients who have hepatic metastases from colorectal cancer resected vs 0% in those who do not [2]. The poor prognosis has been linked to four clinical factors: (1) advanced stage of primary tumor, (2) more than four liver metastases, (3) presence of extrahepatic disease, and (4) less than 30% of normal liver tissue or function remaining after resection. Therefore, candidates for surgery are generally considered to be those in whom histopathologic examination shows no cancer in the margins of the resected primary tumor, those with no extrahepatic metastases, and those with one to four hepatic metastases without known hepatic parenchymal disease [3].

Currently, no single imaging study is optimal for examination of potential surgical candidates. As a result, the radiologic

workup has evolved to include a combination of examinations. We describe our approach to imaging patients with potentially resectable liver metastases, including the limitations and pitfalls of the various techniques.

Dynamic Sequential Bolus Iodine CT

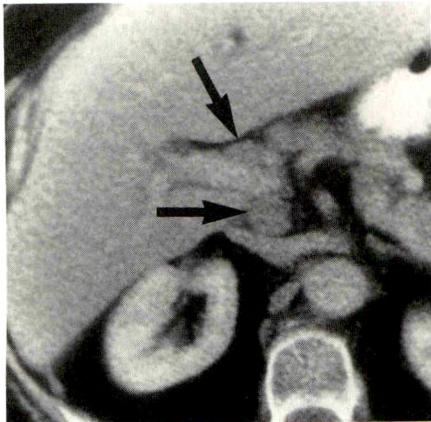
For the purpose of preoperative evaluation, it is essential that contrast-enhanced CT scans be obtained by using a dynamic sequential bolus technique. Oral contrast material for complete bowel opacification is administered before scanning. Although some controversy remains over the optimal method for delivery of contrast material and scan timing, our preferred method of IV contrast administration is designed to take advantage of the maximal lesion-to-liver contrast that occurs with the first 2–3 min after administration. A power injector is used to deliver a 150-ml IV bolus of 60% iodinated contrast material at a rate of 2–3 ml/sec. Scanning begins 30–45 sec after the start of the injection. The entire liver is evaluated with 10-mm contiguous sections during the initial 2–3 min.

This examination will enable exclusion of patients with diffuse hepatic involvement, numerous liver lesions, or extrahepatic disease (Fig. 1). However, dynamic sequential bolus CT may not show up to 28% of metastases found at surgery [4]. Therefore, candidates for surgery require additional studies in order to avoid the morbidity and mortality of surgery in patients who will not benefit from the operation, and to provide

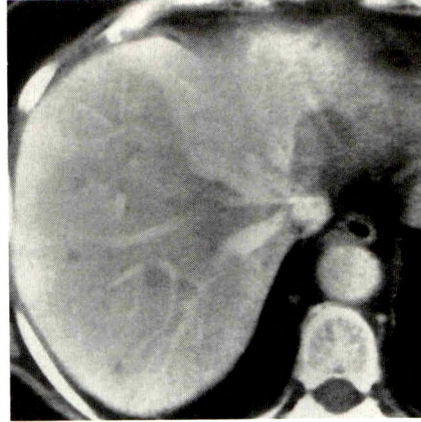
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Fig. 1.—Dynamic CT scan of a patient with a solitary liver metastasis (at another level) shows enlarged lymph nodes (arrows) in porta hepatis and portacaval space. Percutaneous biopsy of porta hepatis lymph node confirmed adenocarcinoma. Patient was excluded as a surgical candidate because of extrahepatic disease.

Fig. 2.—CT scan with arterial portography shows many small metastases in right lobe of liver. These small lesions were not shown by other imaging studies, including dynamic CT or T1-weighted (70/10/1 [TR/TE/excitations]) or T2-weighted (2000/100/4) spin-echo MR images. Perfusion abnormalities also are noted but do not diminish ability to detect lesion.

better preoperative planning for surgical resection in those who remain candidates.

CT with Arterial Portography

Invasive CT techniques, including CT angiography (hepatic arterial injection) and CT with arterial portography (superior mesenteric artery or splenic artery injection), are reserved for patients who are still considered surgical candidates on the basis of less invasive studies. We prefer CT with arterial portography because the images are easier to interpret than are CT angiograms. Our technique involves placement of a 5-French angiographic catheter in either the superior mesenteric or splenic artery. A limited visceral angiogram is then obtained to determine hepatic arterial anatomy (exclude a replaced right hepatic artery) and to determine the infusion capacity of the vessel. Minimal contrast material is used for this portion of the examination so that lesion-to-liver contrast during the CT phase of the examination will not be diminished. The patient is subsequently transferred to the CT scanner, and 150 ml of 60% iodinated contrast material is infused through the catheter at a rate of 2–3 ml/sec via a power injector. Scanning begins 5–10 sec after the start of injection so that scans can be obtained during the portal phase of the arterial infusion. The entire liver is evaluated in 5- to 10-mm contiguous sections during the initial 2–3 min.

This method is reported to be the most sensitive imaging technique for lesion detection, especially lesions less than 2 cm in diameter [5] (Fig. 2). Nontumorous perfusion defects caused by anatomic variation in the hepatic vascular supply may represent the greatest challenge in interpretation of this examination. Perfusion abnormalities may be categorized as technical (improper catheter placement); those extending from hilum to capsule, with or without an obstructing mass (straight-line sign); perihilar and periligamentous; and linear or wedge-shaped subcapsular defects [6].

Precise definition of the hepatic vasculature makes it possible to locate a lesion within one or more of the currently recognized nine liver segments, thus providing assessment of the volume of liver necessary for resection [7].

Although CT with arterial portography is an extremely

sensitive technique, it is nonspecific, and correlation with other imaging studies, such as MR imaging, may be necessary for further characterization of lesions.

Delayed CT with Iodinated Contrast Material

We perform delayed CT with iodinated contrast material in conjunction with CT with arterial portography. The total iodine dose administered during the examination is recorded, and, if necessary, additional iodinated contrast material is administered to bring the total dose to at least 60 g of iodine. CT of the liver with 5- to 10-mm contiguous sections is repeated 4–6 hr later, with no additional preparation of the patient necessary. Normal hepatocytes will excrete up to 2% of administered iodinated contrast material. Hepatic lesions do not excrete contrast material, resulting in focal areas of decreased attenuation. This may enable further clarification of suggested perfusion defects and confirmation of previously detected lesions and patterns of segmental involvement [8] (Figs. 3 and 4).

Biliary obstruction of diffuse hepatocellular disease may diminish excretion of contrast material into bile, which may lower the sensitivity of the technique for detection of focal lesions [8].

MR Imaging

The MR sequences most sensitive for detecting individual liver lesions vary depending on the field strength of the magnet and the machine's specifications. A minimum requirement for hepatic examination includes separate sequences that optimize T1 and T2 contrast. As dictated by the individual equipment, this may incorporate spin-echo, inversion-recovery, or gradient-echo sequences. Additionally, techniques to reduce motion artifacts are essential for hepatic imaging. Our current protocol for MR evaluation of hepatic metastatic disease includes a turbo gradient-echo sequence (180° prepulse, 8/350/3 [TR/TI/TE]) for our T1-weighted sequence and a standard spin-echo sequence (2000/50,100 [TR/TE]) for our T2-weighted sequence. Protocols for hepatic MR continue to undergo rapid change, with an expected continued improve-

Fig. 3.—Perfusion defect seen on CT with arterial portography was clarified by delayed CT.

A, CT scan with arterial portography shows a lesion in right lobe of liver (segment 8, possibly extending into 5, *curved arrow*) and a second lesion in medial segment of left hepatic lobe just anterior to portal vein (*straight arrow*). This is a region where perfusion abnormalities are known to occur.

B, Delayed CT scan shows no lesion in liver anterior to portal vein, confirming suspected perfusion abnormality. Lack of tumor in region was confirmed at surgery.

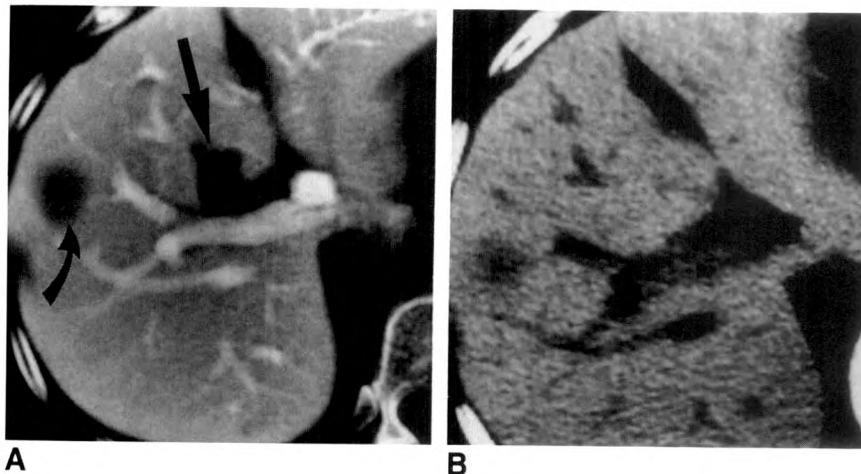
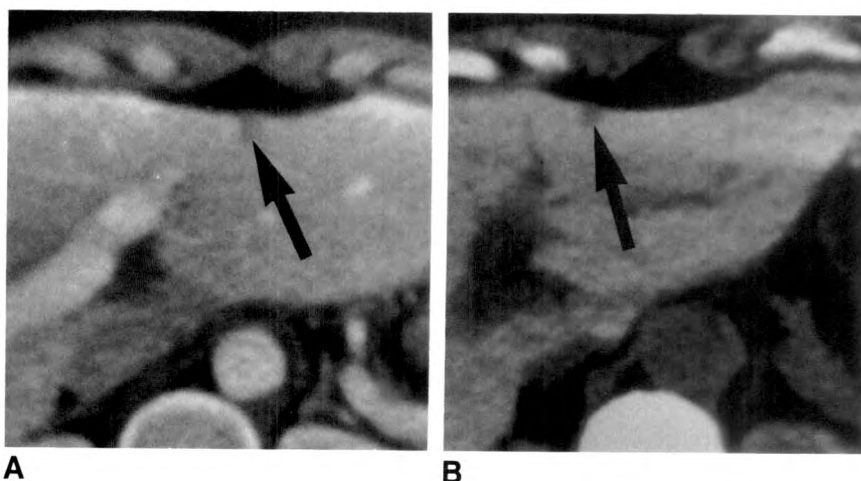


Fig. 4.—Lesion seen on CT with arterial portography was confirmed by delayed CT.

A, CT scan with arterial portography shows a small subcapsular lesion (*arrow*) in lateral segment of left hepatic lobe. Perfusion defects are common in subcapsular region.

B, Delayed CT scan shows this is a true lesion (*arrow*).



ment in sensitivity to disease aided by the development of MR contrast agents targeted at hepatocytes, now currently in the investigational stage. These continued developments merit future comparison of MR with CT with arterial portography to determine the continued need for invasive study in this population of patients.

MR and CT with arterial portography are complementary examinations that have shown a combined sensitivity of 97% for the detection of liver lesions [5]. In addition, on MR images, it may be possible to distinguish malignant lesions from cavernous hemangiomas (Fig. 5). As a single test, MR is limited in the detection of extrahepatic disease if the entire abdomen is not imaged; sensitivity for lesion detection is lower than that of CT with arterial portography [5], and small lesions may be obscured by volume averaging or motion artifacts.

Intraoperative Sonography

After the liver is exposed surgically, a 5.0- or 7.5-MHz transducer encased in a sterile latex sheath is placed on the liver for multiplanar imaging. The sensitivity of this examination is operator dependent, and deep or more posterior tumors may be difficult to detect.

Intraoperative sonography is helpful in further defining problem areas encountered in the preoperative workup. Small (<1 cm) and subcapsular lesions can be well visualized, and cysts can be distinguished from solid lesions. Another important use is to provide identification of vascular landmarks for the surgical dissection.

Discussion

In the workup to determine the resectability of hepatic metastases, several imaging techniques are used to decide which patients may benefit from surgery and exclude those for whom the operative risk is unwarranted.

We recommend that patients who are potential surgical candidates undergo screening dynamic CT initially to exclude diffuse or numerous hepatic lesions as well as extrahepatic disease. This is followed by MR imaging, which may show additional lesions and add specificity to the CT examination. CT with arterial portography, the most sensitive and the most invasive test, is reserved for those patients who are still surgical candidates after noninvasive studies. Delayed CT is a useful adjunct technique for clarification of suspected perfusion abnormalities seen on CT with arterial portography and

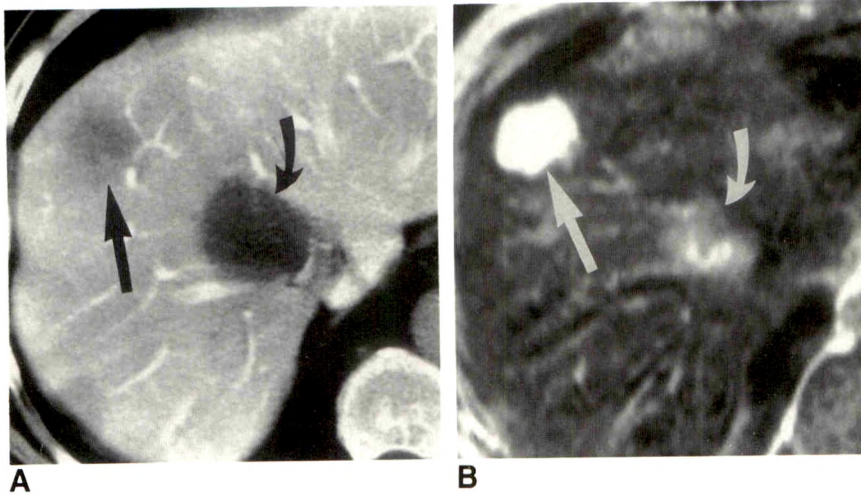


Fig. 5.—MR imaging adds specificity to CT with arterial portography.

A, CT scan with arterial portography in a patient with colonic carcinoma shows hepatic lesions in segments 7 (*curved arrow*) and 8 (*straight arrow*).

B, T2-weighted MR image shows marked difference in lesions' signal characteristics. Subcapsular lesion in segment 8 (*straight arrow*) is sharply defined, homogeneous, and hyperintense. This lesion was a surgically confirmed hemangioma. Central lesion in segment 8 (*curved arrow*) is more heterogeneous and less hyperintense than is hemangioma. This lesion and lesion in segment 7, better seen on an adjacent section, were metastases.

for increasing confidence in lesion detection. This workup allows us to identify those patients in whom the disease extent and location meet the current criteria for surgical resection and potential long-term disease-free survival. Intraoperative sonography is useful as a problem-solving technique after a meticulous preoperative workup.

Despite the use of a combination of imaging studies, small-volume peritoneal seeding and involvement of paraduodenal and porta hepatis lymph nodes are frequently not identified preoperatively. These are common reasons for aborting a planned resection after surgical exploration [3]. Future improvements in imaging technology may improve disease detection in these areas.

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Color Flow Doppler Characterization of Focal Hepatic Lesions

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OBJECTIVE. The purpose of this study was to determine the sensitivity and specificity of color flow Doppler sonography for the specific diagnosis of focal hepatic lesions.

SUBJECTS AND METHODS. Color flow Doppler images of 118 focal hepatic lesions in 108 patients were analyzed prospectively. In most patients, liver disease was suspected or known to be present before the Doppler images were obtained. Experienced sonologists obtained and interpreted all sonograms. The lesions were classified, according to their color flow pattern, into two main categories: lesions with internal vascularity and lesions with no internal vascularity. The color flow Doppler pattern of each lesion was correlated with the diagnosis of the lesion on a lesion-by-lesion basis. One hundred two lesions were proved by biopsy and 16 lesions were confirmed by evaluation with other imaging techniques. Lesions included 29 hepatocellular carcinomas, 64 metastases, one cholangiocarcinoma, and 24 benign lesions. The sensitivity and specificity of vascularity as shown by color Doppler imaging in the diagnosis of hepatocellular carcinoma were determined.

RESULTS. The majority of hepatocellular carcinoma lesions (76%) had internal vascularity. Most of the metastases (67%) and benign lesions (75%) had no internal vascularity. When the presence of internal vascularity was used as the discriminating criterion, the sensitivity of color flow Doppler findings for the diagnosis of hepatocellular carcinoma was 0.76. The specificity of internal vascularity for the diagnosis of hepatocellular carcinoma vs other focal lesions was 0.69; for hepatocellular carcinoma vs metastases it was 0.67.

CONCLUSION. Although most hepatocellular carcinomas have internal vascularity on color flow Doppler images, a significant number of metastases also have internal vascularity. This overlap limits the usefulness of color flow Doppler imaging for distinguishing hepatocellular carcinoma from metastatic tumors.

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Color flow Doppler imaging is a major advance in sonography of mass lesions because it enables the sonologist to determine the patterns of blood flow within and around such lesions. This, in turn, may enable the sonologist to determine the nature of the lesion with much greater precision. Liver lesions, in particular, are difficult to differentiate from each other by using conventional sonography. In 1990, Tanaka et al. [1] attempted to differentiate hepatocellular carcinoma (HCC) from other liver mass lesions on the basis of the patterns of blood flow within and around the lesion on color flow Doppler images. They described four patterns: a fine blood-flow network surrounding the tumor nodule (basket pattern), blood flow running into and branching within the tumor (vessels-within-the-tumor pattern), color-stained dots or patches in the central region of the tumor (spot pattern), and a dilated portal vein meandering around the tumor nodule (detour pattern). Their results suggested that the basket and vessels-within-the-tumor patterns were characteristic of HCC, that the spot pattern occurred most frequently in hemangiomas, and that the detour pattern was observed in metastases. However, Tanaka et al. examined only 35 patients, most of whom (20 patients) had HCC. Only four

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patients in their series had metastases. The relative distribution of tumor type in their series differs significantly from that usually encountered in practice, which limits the usefulness of their study.

The purpose of this study was to determine the sensitivity and specificity of color flow Doppler sonography for the diagnosis of focal hepatic lesions based on the presence or absence of internal vascularity.

Subjects and Methods

The color flow Doppler patterns of 118 focal hepatic lesions in 108 adult patients, 58 men and 50 women 20–91 years old (average age, 69 years), were analyzed prospectively. In most patients, liver disease was suspected or known to be present before the Doppler images were obtained, and most were referred for biopsy under sonographic guidance.

All patients were examined with either the Acuson 128 or the Acuson XP unit (Acuson, Mountain View, CA). Focused phased-array or curved-array probes ranging from 3.5 to 5 MHz were used. The color flow imaging parameters (power output, gate size, color sensitivity) were optimized for each patient to enhance visualization of the internal vasculature of the focal hepatic lesions. The color Doppler filters used were numbers 1, 2, and 3. Filter number 1, a low-volume flow filter with a high degree of motion discrimination, was the most frequently used. Experienced sonologists performed and interpreted all examinations.

The color flow Doppler pattern of each lesion was categorized into one of two categories: lesions with internal vascularity (basket, vessels-within-the-tumor, and spot patterns) and lesions with no internal vascularity (detour and avascular patterns). Although every attempt was made to classify each lesion according to the specific patterns described by Tanaka et al. [1], it was rather difficult to match those patterns exactly. Therefore, we chose to stratify the lesions on the basis of the presence or absence of internal vascularity. The color flow Doppler pattern of each lesion was later correlated with histologic findings on a lesion-by-lesion basis. In patients with more than one hepatic lesion, the largest lesion was analyzed if the lesions had the same sonographic appearance; lesions with different sonographic appearances were analyzed separately.

The 118 focal hepatic lesions included 29 HCCs, 64 metastatic lesions, one cholangiocarcinoma, 12 hemangiomas, one focal nodular hyperplasia, five abscesses, one hematoma, three areas of focal fatty infiltration, and two regenerating nodules.

The diagnosis was confirmed by histology for all HCCs, all metastases, and eight of the 24 benign lesions. In patients with HCC, tissue was obtained at surgery in one patient and by percutaneous biopsy in 28. In patients with metastases, tissue was obtained surgically in five and by percutaneous biopsy in 59. Tissue was obtained by percutaneous biopsy in two regenerating nodules, one focal nodular hyperplasia, and one of five abscesses, and by percutaneous drainage in the other four abscesses. In the remaining 16 benign lesions, the diagnosis was made on the basis of other imaging findings (including CT, MR, angiographic, and scintigraphic findings). Under these circumstances, it was considered unnecessary to obtain a biopsy of these lesions. For 12 patients, the unequivocal diagnosis was hemangioma; five diagnoses were based on CT findings, four on MR findings, one on CT and MR findings, one on angiographic and MR findings, and one on scintigraphic findings. In three patients, areas of fatty infiltration were confirmed by MR findings in two and by CT in one. The diagnosis of hematoma was made in one case by using both CT and MR. This study was not designed to compare

lesion vascularity demonstrated by Doppler studies with the vascularity demonstrated by other imaging studies.

The sensitivity and specificity of vascularity as shown by color Doppler imaging in the diagnosis of HCC were determined.

Results

Correlation between the final diagnosis and the color flow Doppler pattern of the 118 focal hepatic lesions (Table 1) showed 50 lesions with internal vascularity. These included 22 (76%) of 29 HCCs (Fig. 1A), 21 (33%) of 64 metastases (Fig. 1B), one (100%) of one cholangiocarcinoma, and six (25%) of 24 benign lesions. Sixty-eight lesions showed no internal vascularity. These included seven (24%) of 29 HCCs (Fig. 2A), 43 (67%) of 64 metastases (Fig. 2B), and 18 (75%) of 24 benign lesions.

Fifty-one of 64 metastatic lesions originated from 17 primary sites and the other 13 were adenocarcinomas from unknown primary sites. Twenty-one metastatic lesions had internal vascularity. The patterns were vessels-within-the-tumor in 14, basket in four, and spot in three. Of the 43 metastatic lesions with no internal vascularity, 26 showed a detour pattern and 17 were avascular. Metastatic lesions with internal vascularity included three of 18 adenocarcinomas of the colon, three of three poorly differentiated adenocarcinomas of the esophagus, two of two squamous cell carcinomas of the rectum, one of two carcinomas of the gallbladder, one of four breast carcinomas, one of three melanomas, one of one squamous cell carcinoma of the cervix, one of one leiomyosarcoma, and eight of 13 adenocarcinomas of unknown origin.

The six benign lesions with internal vascularity were one hemangioma, three areas of focal fatty infiltration, one focal nodular hyperplasia, and one abscess. The reason for the presence of internal vascularity in this abscess is unclear. Presumably this abscess was in an early stage of evolution prior to liquefaction.

Nine patients had lesions that had more than one color flow pattern. Four of these patients had lesions with internal vascularity but with different subtypes: basket, vessels within the tumor, and spot (two multifocal HCCs and two metastases). The other five patients had some lesions with internal vascu-

TABLE 1: Correlation Between Pattern on Color Flow Doppler Imaging and Final Diagnosis of Focal Hepatic Lesions

Diagnosis	No.	Pattern	
		Internal Vascularity	No Internal Vascularity
Hepatocellular carcinoma	29	22	7
Cholangiocarcinoma	1	1	0
Metastasis	64	21	43
Hemangioma	12	1	11
Focal nodular hyperplasia	1	1	0
Abscess	5	1	4
Hematoma	1	0	1
Fatty infiltration	3	3	0
Regenerating nodule	2	0	2
Total	118	50	68

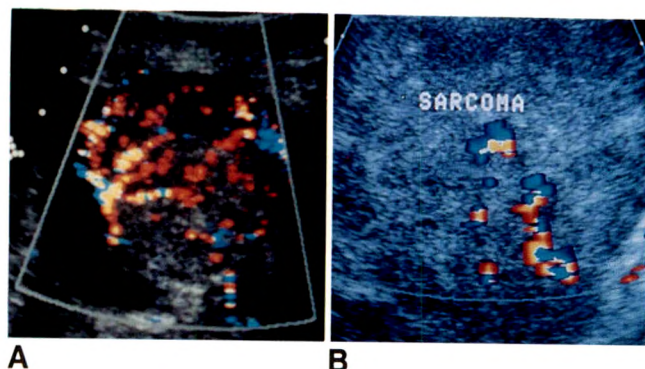


Fig. 1.—Color flow Doppler images of focal hepatic lesions with internal vascularity.

- A, Hepatocellular carcinoma has blood flow within tumor mass.
B, Metastatic lesion from a sarcoma has abundant vascular flow within tumor nodule.

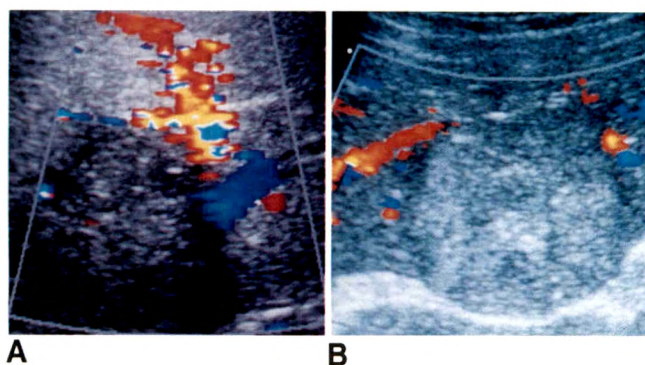


Fig. 2.—Color flow Doppler images of focal hepatic lesions with no internal vascularity.

- A, Hepatocellular carcinoma has a dilated, tortuous vessel surrounding tumor nodule. No vascular flow is seen inside tumor mass.
B, Metastatic lesion from adenocarcinoma of colon has vessels surrounding tumor nodule. Internal vascularity is not present.

larity and some with no internal vascularity (one multifocal HCC and four metastases).

Since most patients underwent needle biopsy, either percutaneously or surgically, the specimen obtained contained insufficient tissue for the pathologist to determine the vascularity of the lesion or whether the lesion was necrotic.

The majority of HCC lesions (76%) had internal vascularity. When the presence of internal vascularity is used as the discriminating criterion, the sensitivity of color flow Doppler imaging for the diagnosis of HCC was 0.76. The specificity of internal vascularity for the diagnosis of HCC vs other focal liver lesions was 0.69 and for HCC vs metastases, 0.67. Metastases were more frequently (67%) lesions with no internal vascularity. Benign lesions were primarily (75%) lesions with no internal vascularity.

Discussion

Color flow Doppler imaging has become a valuable method for the evaluation of the vascular supply of abdominal and

pelvic organs and for obtaining clinically useful information related to organ perfusion and tumor vascularity. The vascularity of focal hepatic lesions has been evaluated with pulsed Doppler sonography [2–4] and with color flow Doppler imaging [1, 5].

In 1987, Taylor et al. [2] described the presence of high-velocity Doppler signals in HCC, which correlated with the angiographic findings of arteriovenous shunting frequently found in HCC and not in other liver lesions such as hemangiomas and metastases. Similar findings have been reported in subsequent studies ([3, 4], and Hammers et al., presented at the Radiological Society of North America meeting, December 1991) on the use of pulsed Doppler imaging in the differential diagnosis of focal hepatic lesions.

Tanaka et al. [1] used color flow Doppler imaging to differentiate HCC from other focal hepatic lesions. In their study, the sensitivity of basket and vessels-within-the-tumor patterns as shown by color flow Doppler imaging for the diagnosis of HCC was 80%. The specificity for the diagnosis of HCC vs other focal hepatic lesions was 100%. In our study, although most HCCs (76%) had the basket and vessels-within-the-tumor patterns, these patterns were also seen in 33% of the metastases. Metastases from 17 different primary sites were included in our study. No specific pattern of vascularity was associated with a given primary site. However, the number of metastases from each primary site was too small to warrant statistical analysis.

In our series, only one of 12 hemangiomas showed internal vascularity. In this one case, the pattern was that of vessels within the tumor rather than the spot pattern seen in 50% of the hemangiomas in the study by Tanaka et al. [1].

In actual practice, it is often difficult to determine precisely which specific internal vascular pattern is present. Therefore, we stratified lesions according to the presence or absence of internal vascularity on color flow Doppler imaging. These two categories are more easily distinguished and might be used for the differential diagnosis of focal hepatic lesions.

The results of this study show that although most HCCs have internal vascularity on color flow Doppler images and most metastases have no internal vascularity, overlap between the two patterns is significant. This limits the overall usefulness of color flow Doppler imaging for distinguishing HCC from metastatic tumors. Furthermore, the majority of both benign and metastatic lesions had no internal vascularity on color flow Doppler sonography.

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Nominal Dysphasia

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Medical nomenclature is both arcane and voluminous. Between 60,000 and 100,000 anatomic parts, diseases, syndromes, eponyms, diagnostic tests, physiologic and pathologic processes, biochemical compounds, drugs, therapeutic procedures, and operations are cited in medical dictionaries. This constitutes a lexicon as large as the vocabulary of most languages, and it is not surprising that errors in nomenclature are common in medical publications. The following are examples of such errors culled from the recent radiologic literature:

The ampulla of Vater. As Marvin Daves [1] has pointed out: "There is no ampulla at the confluence of the bile and pancreatic ducts." The confluence of these ducts is always characterized by a tapering of the lumen. The word ampulla (Latin: *ampulla* = a flask or bottle) implies a widening of the lumen, which is not seen normally. Therefore this segment should not be called the *ampulla of Vater*, but rather the conjoint duct, vaterian segment [1], or, simply, confluence of common bile duct and pancreatic duct. Unlike the illusory ampulla of Vater, the *papilla of Vater*, or greater duodenal papilla, through which the conjoint duct enters the duodenum, is a real structure that can be clearly seen in anatomic specimens and often on upper gastrointestinal examinations.

The common duct. There are two common ducts in the biliary tree: the common hepatic duct and the common bile duct. The term common duct is therefore ambiguous, and either *common hepatic duct* or *common bile duct* should be specified.

The cavum septum pellucidum. The septum pellucidum is a translucent partition (Latin: *saeptum* = a barrier; *pellucere* = to shine through) between the two lateral ventricles. It sometimes comprises two leaves with a space (Latin: *cavum* = a cavity) between them. This space is therefore the *cavum septi pellucidi* (cavity of the septum pellucidum). The possessive—genitive case in Latin (*septi pellucidi*)—is used to denote of the *septum pellucidum*.

The dorsum sella. The posterior wall of the sella turcica (Latin: *dorsum* = back; *sella* = seat; *turcica* = Turkish) is the *dorsum sellae* (back of the sella). Again, the Latin possessive or genitive case (*sellae*) is used to denote of the *sella*.

The calvarium. The Latin word for the domelike, upper portion of the skull is *calvaria*. Although *calvarium* is commonly used, it is incorrect [2] and should be replaced by *calvaria*.

Ileus. This word comes from the Greek: *eileos* meaning intestinal colic [2]. It is often misused to mean exactly the

reverse: a paralyzed bowel. For clarity, the term ileus should always be qualified: *adynamic (or paralytic) ileus* due to paralysis of the bowel, *dynamic ileus* due to spasm of a segment of bowel, or *mechanical ileus* due to a structural block.

Contrast allergy. Adverse reactions to radiographic contrast media are *idiosyncratic* reactions that do not fulfill the criteria for true allergic reactions [3]. The term allergy should not be used.

Thoracic outlet syndrome. There is considerable confusion as to whether the opening at the cranial end of the thorax is the thoracic inlet or outlet. One author recently hedged his bet by writing: "The thoracic *outlet* syndrome is caused by compression of the neurovascular bundle at the thoracic *inlet*" [italics mine]. Standardization on a single term—either inlet or outlet—is desirable, and confusion can be avoided by defining the term used.

Mucus membranes. The word mucus comes from the Latin: *mucus* meaning—you guessed it—mucus. *Mucus* is a noun, not an adjective. When used as an adjective, it becomes *mucous*, hence mucous membranes, mucous glands, mucous secretions.

EKG, V/Q scan. In the early years of the 20th century, most American physicians who desired foreign postgraduate training went to Germany. The abbreviation EKG for *elektrokardiogram* dates from this era. Very few physicians know the meaning of the "Q" in V/Q scan. It comes from the German word *Quellung*, meaning flow. When EKG and V/Q scan are written out in full in the American medical literature, they are invariably written as electrocardiogram and ventilation/perfusion scan. For consistency, therefore, the abbreviations EKG and V/Q scan should be replaced by ECG and V/P scan.

Portable X-ray machine. Unless your X-ray technologist is built like Arnold Schwarzenegger, it is unlikely that he or she can carry one of these machines (portable comes from the Latin: *portare* = to carry). The correct term is *mobile X-ray machine* (mobile comes from the Latin: *mobilis* = movable).

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Editor's note.—This is one of several vignettes, which will appear periodically in *AJR*, examining some of the common pitfalls of medical writing. The intent is to help authors communicate their observations and discoveries clearly and in accordance with accepted grammatical style.

Reversed or Absent Hepatic Arterial Diastolic Flow in Liver Transplants Shown by Duplex Sonography: A Poor Predictor of Subsequent Hepatic Artery Thrombosis

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Kathleen A. Scanlan

OBJECTIVE. We studied the value of absent or reversed diastolic flow in the hepatic artery, shown by duplex sonography of recently transplanted livers, in predicting subsequent hepatic artery thrombosis.

MATERIALS AND METHODS. We retrospectively reviewed the records of liver transplantations performed in adults during a 3-year period at our institution. Duplex Doppler studies were done within 24 hr after transplantation and subsequently reviewed. The clinical course of all patients with absent or reversed diastolic flow in the hepatic artery immediately after transplantation was evaluated.

RESULTS. Of the 160 liver transplants included in this study, 30 had aberrant diastolic flow in the hepatic artery immediately after transplantation. Twenty had reversed flow, and 10 showed no flow in diastole. In this group of 30 transplants, complications developed in six; two were vascular in origin. One of these complications was thrombosis of the hepatic artery 12 months after transplantation. This 3% thrombosis rate is similar to the 4.6% thrombosis rate of the 130 patients who had antegrade diastolic flow in the hepatic artery immediately after transplantation.

CONCLUSION. Reversed or absent diastolic flow in the hepatic artery of a recently transplanted liver has no correlation with subsequent hepatic artery thrombosis.

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Liver transplantation has become the treatment of choice for a variety of end-stage liver diseases. Coincident with the development of liver transplantation, various radiologic techniques have been used to examine the transplant recipients. Duplex Doppler and color flow sonographic imaging have become the mainstays for evaluation of the transplanted liver. This noninvasive, relatively inexpensive imaging technique is the primary screening tool before and after surgery. It is used to show patency of all the vessels in the transplanted liver and to develop a profile of the vascular dynamics. Antegrade flow is normally present in the hepatic artery throughout diastole because of the low impedance in the hepatic vascular bed [1, 2]. When the results are abnormal (i.e., nonvisualization of the hepatic arterial waveform), further studies, usually arteriography, are done.

Thrombosis of the hepatic artery is a serious complication of liver transplantation. Arterial thrombosis is most common within the first 6 weeks after transplantation [1]. Patients have not had time for collateral vessels to develop, and thrombosis is usually catastrophic, with loss of the new liver. Clinical presentations of late thrombosis of the hepatic artery include recurrent episodes of sepsis and biliary tract problems, including biliary stenoses and leaks.

In reviewing the duplex Doppler studies of our liver transplant recipients, we noted a significant percentage that lacked antegrade diastolic flow in the immediate postoperative period. Longley et al. [3] suggested that the absence of diastolic flow in the hepatic artery after transplantation did not correlate with acute rejection. However, we are not aware of data on normal and abnormal variations in hepatic arterial diastolic flow in recently transplanted organs. Kubota et al. [4] suggested

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that the absence of diastolic flow in the transplanted liver may be a poor prognostic sign, because thrombosis of the hepatic artery subsequently developed in one such patient in their study. We retrospectively reviewed the diastolic flow patterns in the hepatic artery shown by sonography immediately after liver transplantation to determine if absence or reversal of diastolic flow was associated with subsequent hepatic artery thrombosis.

Materials and Methods

We reviewed the records of 230 consecutive liver transplantations performed at the University of Wisconsin, Madison, from October 1988 through October 1991. Patients less than 18 years old were excluded from the study (55 liver transplants). Although hepatic arterial thrombosis may occur in children, collaterals develop rapidly and usually maintain the viability of the liver. Five patients who did not have duplex Doppler sonography within 24 hr after transplantation also were excluded, as were four patients who did not have sonography because of immediate retransplantation or death and six patients for whom no sonograms were available for review. The remaining 147 adults (160 transplants) formed the basis of the study.

All patients were examined with real-time and pulsed Doppler sonography by using an Acuson 128 unit (Mountain View, CA). Color Doppler imaging also was used when it became available. Intercostal or subcostal approaches were used to evaluate the main hepatic artery in the porta hepatis; 2.0- or 3.5-MHz transducers were used, depending on the patient's habitus.

We reviewed the Doppler waveforms of the hepatic artery with attention to arterial diastolic flow. Findings were categorized into one of three patterns: forward flow throughout diastole, no flow in diastole, and reversed flow in diastole. For patients who had diastolic patterns other than forward flow, we then reviewed follow-up serial imaging studies or the records of clinical follow-up examinations.

Twenty-five of the 30 patients who did not have forward flow had follow-up imaging. These follow-up examinations were done at various intervals, from 2 days to 7 months after transplantation. The records of all 30 patients were reviewed to determine the clinical courses. Clinical follow-up examinations were done from 6 weeks to 2 years 6 months after transplantation.

Results

Antegrade diastolic flow was seen in 130 (81%) of the 160 liver transplants studied, and thrombosis of the hepatic artery developed in six (4.6%) of these. In the 30 remaining liver transplants, diastolic flow was absent (10) or reversed (20) in the immediate postoperative period. All of these liver transplants had normal portal venous flow. This group of patients had a wide range of causes of liver failure, including alcoholic cirrhosis (11), hepatitis B (nine), sclerosing cholangitis (four), primary biliary cirrhosis (two), Wilson's disease (one), and unspecified causes (three).

Of these 30 liver transplants, 24 are doing well; follow-up has ranged from 6 weeks to 2 years 6 months. Follow-up has been less than 2 months in only three cases. Forward flow in diastole developed eventually in all of the liver transplants in this group (Fig. 1).

Complications developed in the remaining six liver transplants. All of these had reversed diastolic flow on the initial study. Hepatocellular carcinoma developed in one of the liver transplants 15 months after transplantation. Two of the transplanted livers had primary nonfunction, and retransplantation was required 2 and 3 days after the initial transplantation. The fourth liver transplant had improved diastolic flow 5 days after transplantation. However, because of recurrent problems, hepatic arteriography was performed 4 months later and showed stenosis of the hepatic artery. Thrombosis of the hepatic artery developed in the fifth liver transplant 12 months after transplantation. Neither the fourth nor the fifth liver transplant was evaluated with sonography immediately before arteriography. The sixth liver transplant had elevated liver enzyme levels, and an arteriogram obtained 10 weeks after transplantation showed a patent hepatic artery with no stenosis.

Discussion

Hepatic artery thrombosis is a devastating postoperative complication, because in adult patients, the liver transplant

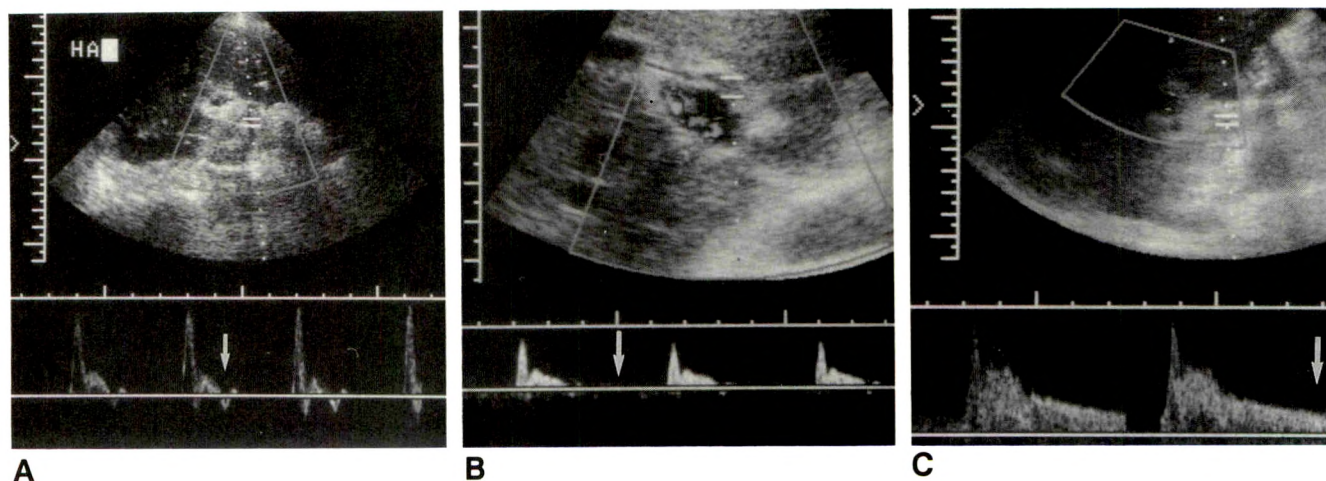


Fig. 1.—A–C, Evaluation of hepatic arterial diastolic flow after liver transplantation. Doppler sonograms obtained 1 day (A), 2 days (B), and 4 months (C) after transplantation show immediate postoperative reversal of flow (arrow) during diastole (A), followed by absence of flow (arrow in B), and then return of flow (arrow in C).

will usually fail. (The average rate of hepatic artery thrombosis in adult recipients of liver transplants is 3–12% [5–7].) Duplex sonography has become the initial method to evaluate the liver transplant because it is quick, noninvasive, and can be performed at the bedside. Not only does duplex sonography provide information regarding the hepatic vasculature but also the liver parenchyma, biliary system, and adjacent processes such as fluid collections. If duplex sonography fails to show a hepatic arterial waveform, then arteriography to evaluate the hepatic artery should be considered. Flint et al. [8] found that 92% of their cases of hepatic artery thrombosis were correctly identified by use of duplex sonography, and only 8% of patients with thrombosis of the hepatic artery had a duplex Doppler study that falsely indicated a patent hepatic artery. Flint et al. [8] were unable to show flow in liver transplants that had developed arterial collaterals due to thrombosis of the hepatic artery. However, other studies have shown causes in which collateral arterial flow was mistaken for a patent main hepatic artery in children. Hall et al. [9] noted this problem in children who had an arterial Doppler signal but, in fact, had hepatic arterial thrombosis with formation of collaterals shown by arteriography. For this reason and because we did not have arteriograms of all our patients, we excluded all children from our study.

We did this retrospective study to determine if variations in the diastolic flow in the hepatic artery observed on Doppler sonograms obtained immediately after liver transplantation correlated with subsequent thrombosis of the hepatic artery. Absence or reversal of flow in diastole does not appear to indicate a predisposition for thrombosis. This finding was associated with subsequent thrombosis of the hepatic artery in one of 30 cases. Interestingly, in all 25 of the patients who had follow-up sonography, the pattern of diastolic flow eventually became normal. Some patients had only an initial Doppler study, and clinical follow-up was used to evaluate the patency of the hepatic artery indirectly. Because the early development of collateral vessels sufficient to support the liver in adults is rare, we accepted the absence of complications in clinical follow-up as indirect evidence that the hepatic artery was patent [5].

We had surmised initially that absent or reversed diastolic flow in the recently transplanted liver would be a good prognostic sign for subsequent thrombosis. Absence or reversal of diastolic flow indicates abnormally high impedance in the hepatic vasculature, with an associated possible decrease in blood flow. This situation may lead to an increased risk of thrombosis. The concept of decreased diastolic flow being associated with complications in the liver transplant has been

studied before. Marder et al. [10] studied the resistive index and its relationship to acute rejection. Longley et al. [3] studied the loss of hepatic arterial diastolic flow and the relationship to acute rejection. Neither study found a correlation between acute rejection and elevated resistive index or loss of hepatic arterial diastolic flow.

One would surmise that if vascular impedance in the liver were sufficient to affect the diastolic hepatic arterial waveform, then the portal venous Doppler waveforms also could be affected. As we have not found associated changes in the Doppler waveforms of the portal vein, we speculate that the loss of diastolic flow may be due to a specific problem in the arterial system rather than a more widespread problem in the liver. One consideration is that this phenomenon is related to arterial vasospasm, which may be caused by the preservation techniques, transient hypoxia, or surgical procedures. However, we do not have any models to explain this phenomenon. The cause of reversed or absent diastolic hepatic arterial flow in the recently transplanted liver is unknown. On the basis of this retrospective study, absence or reversal of hepatic arterial diastolic flow in the recently transplanted liver does not appear to be a prognostic indicator of impending hepatic arterial thrombosis.

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Untitled. Carmel, CA, 1992

Tahnee Marsh¹



This photograph was taken in daylight with film that is sensitive to infrared rays—the long waves that lie outside the red end of the visible spectrum. Green plants absorb almost no infrared light, so they reflect most of the radiation and appear ghostly white on photographs taken with infrared film. Most other natural elements, such as rocks, sand, wood, and soil are similarly reflective, causing them to photograph the same way.

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Pictorial Essay

Filling Defects in the Pancreatic Duct on Endoscopic Retrograde Pancreatography

Andrew J. Taylor,¹ Timothy J. Carmody,¹ Michael J. Schmalz,² Debra A. Wiedmeyer,¹ and Edward T. Stewart¹

Filling defects in the pancreatic duct are a frequent finding during endoscopic retrograde pancreatography (ERP) and have a variety of causes. Some filling defects may be artifactual or related to technical factors and, once their origin is recognized, can be disregarded. Others may be due to acute changes of pancreatitis and should prompt more careful injection of contrast material into the duct. Intraluminal masses may represent calculi or a neoplasm, either of which may require surgery or endoscopic intervention. The exact nature of these filling defects may not be apparent on radiographs, and other studies may be needed. This article reviews our approach to the evaluation of filling defects in the pancreatic duct.

Artifacts

The most common intraluminal filling defect is the injected air bubble. Although the catheter should be cleared of all air by aspiration or flushing before injection, occasionally some air remains in the catheter and is introduced into the pancreatic duct when contrast material is injected. These air bubbles are usually easily recognized by their round or slightly oval shape, conforming to the shape of the duct. They are often multiple and contiguous in distribution (Fig. 1). At fluoroscopy, air bubbles may be seen to move easily with injection of a small amount of contrast material, or may be visualized as they are injected from the catheter tip. They can be aspirated back into the catheter. As the patient's position is altered, air bubbles in the pancreatic duct will rise to the

highest portion of the duct. A large column of air may interfere with complete opacification of the main pancreatic duct, and acinarization of the pancreas may occur as more contrast material is injected to fill the air-locked segment. The presence of air in the pancreatic duct also can simulate a stricture or be mistaken for a ductal obstruction.

Contrast material extravasated during injection may mimic an enlarged, distorted pancreatic duct filled with an irregular intraluminal mass (Fig. 2; compare with Fig. 11). Although infrequent, extravasation usually occurs when seating the catheter tip within the pancreatic duct before injection is difficult, or after unintentional cannulation of a side branch of the pancreatic duct.

Inflammation

Inflammation of the pancreas may result in many different types of intraductal filling defects. The most common defects are pancreatic duct calculi. Proteinaceous plugs are associated with chronic inflammation of the pancreas. Invariably, these plugs accrue calcium carbonate and develop into calcified intraductal stones, a relatively late finding seen in chronic calcific pancreatitis. At ERP, these foci may or may not show calcification, depending on their stage of development. A preliminary radiograph is helpful in showing calcification of these stones, which may be obscured by subsequent injection of contrast material. CT has a higher sensitivity in defining subtle calcifications in the pancreas (Fig. 3). An-

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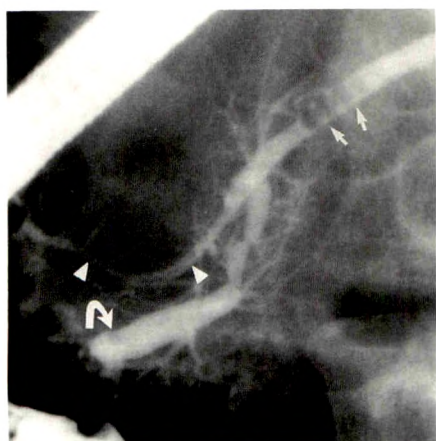
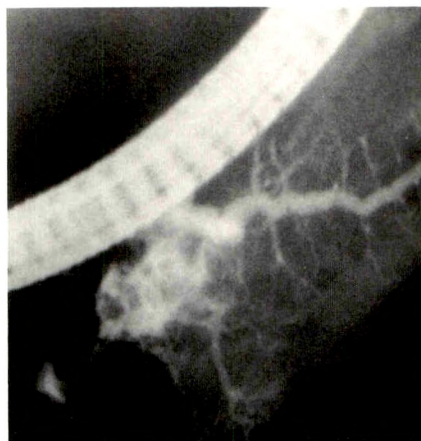
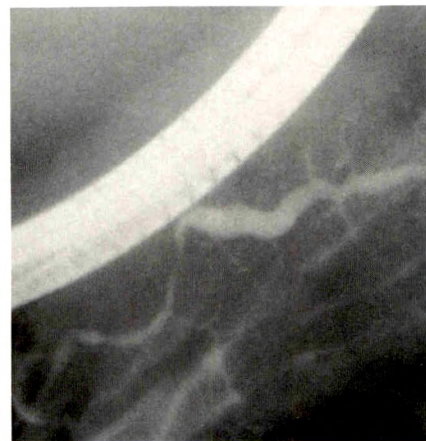


Fig. 1.—Air bubbles. Endoscopic retrograde pancreatogram in a man with suspected pancreatic mass shows four filling defects (straight arrows) in proximal body of pancreatic duct. Note round and oval appearance of four masses contiguously arranged within duct. At tip of catheter, an air bubble is being injected (curved arrow). Also note draping of duct of Santorini from a mass in pancreatic head (arrowheads).



A

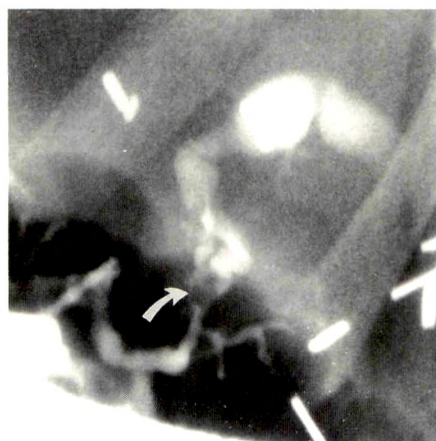


B

Fig. 2.—Extravasation of contrast material simulating a mass.

A, Seating of cannula before injection of contrast material into pancreatic duct was difficult. After injection of contrast material, it is unclear whether endoscopic retrograde pancreatogram (ERP) shows pancreatic head to have a large, distorted duct filled with a mass, or if this appearance is related to extravasation. Presence of a nonobstructed duct proximally suggests a technical cause.

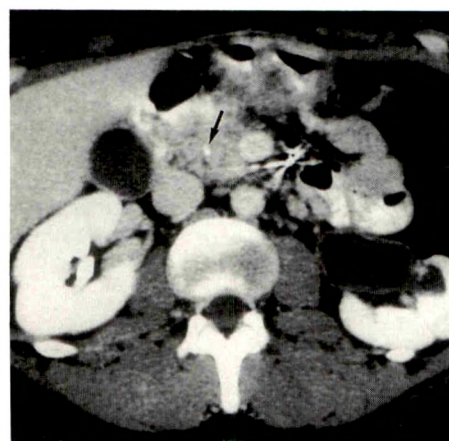
B, 3 months later, ERP shows diffuse narrowing of distal duct due to chronic pancreatitis with no mass present. Appearance of duct at this examination was similar to that seen at ERP 1 year earlier.



A



B



C

Fig. 3.—Correlation of CT and endoscopic retrograde pancreatographic (ERP) findings in diagnosis of pancreatic calculi. A patient who had had partial pancreatectomy for chronic alcoholic pancreatitis presented with increasing pain.

A, ERP shows a filling defect (arrow) in distal portion of pancreatic duct just proximal to a stricture. The technologist had changed syringes just before this injection so an air bubble may have been introduced.

B, ERP obtained after patient had been rotated still shows a filling defect (arrows), which is now smaller.

C, CT scan shows a small calcification (arrow) in head of pancreas corresponding to location of intraductal defect, thereby confirming diagnosis of a tiny, intraductal stone.

gular borders, multiplicity, and mobility may differentiate calculi from other filling defects (Fig. 4). When ductal stones are thought to be the cause of abdominal pain, surgery or endoscopic intervention may be appropriate to relieve the obstruction of the pancreatic duct.

A more unusual finding in chronic inflammatory disease of the pancreas is the presence of a gelatinous cast within the main pancreatic duct. Although such casts are usually associated with some neoplasia, we have noted two such cases associated with pancreatitis (Figs. 5 and 6).

Rarely, numerous small filling defects are seen in the main pancreatic duct in patients with acute pancreatitis (Fig. 7). Although ERP is contraindicated in the acute phase of pancreatitis, the pancreatic duct may be inadvertently injected during an attempt to visualize the common bile duct to check for choledocholithiasis as a cause for the pancreatitis. These filling defects are thought to be related to debris from pancreatic autodigestion.

When pancreatitis is associated with formation of pseudocysts, the pseudocyst will fill with contrast material during

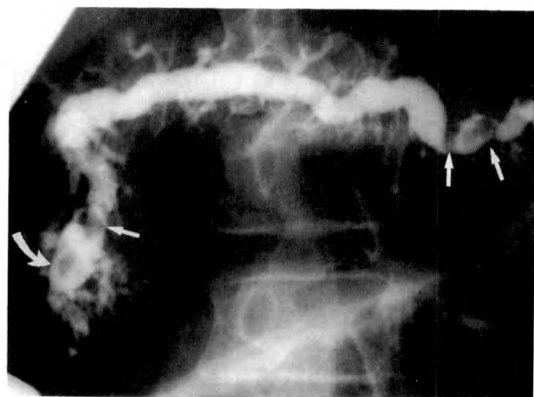


Fig. 4.—Calculi of chronic pancreatitis. Endoscopic retrograde pancreatogram shows findings of irregular and ectatic duct with clubbing of side branches, typical for chronic pancreatitis. In addition, multiple faceted stones are seen (straight arrows) in both head and tail of pancreas. Compare these with large, smooth air bubble (curved arrow) just above tip of catheter.

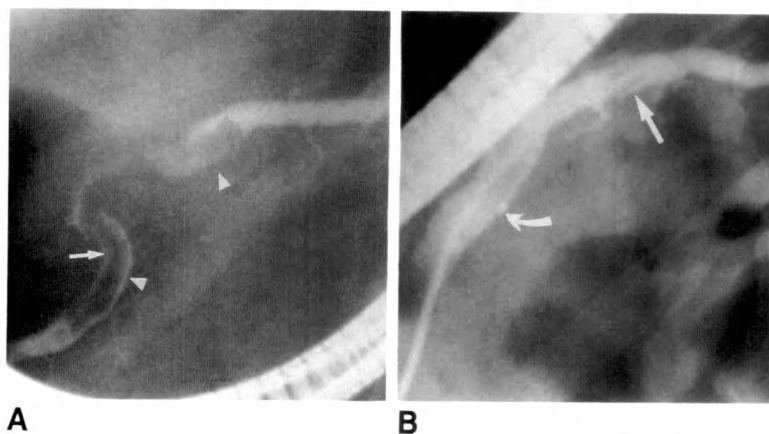


Fig. 5.—Gelatinous cast associated with chronic pancreatitis. A 57-year-old patient with a history of alcohol abuse 20 years earlier had clinical signs and symptoms of chronic pancreatitis for 2 years.

A, Endoscopic retrograde pancreatogram (ERP) shows a long intraluminal cast (arrowheads) during initial injection of contrast material. Tip of cannula is seen (arrow).

B, Subsequently, ERP shows a balloon-tip catheter (straight arrow) placed proximal to cast (curved arrow) that eventually is withdrawn from duct. A subsequent CT scan (not shown) was unremarkable. At surgery for sphincterotomy, the pancreas showed evidence of pancreatitis but no mass lesion. The patient was asymptomatic 18 months later.

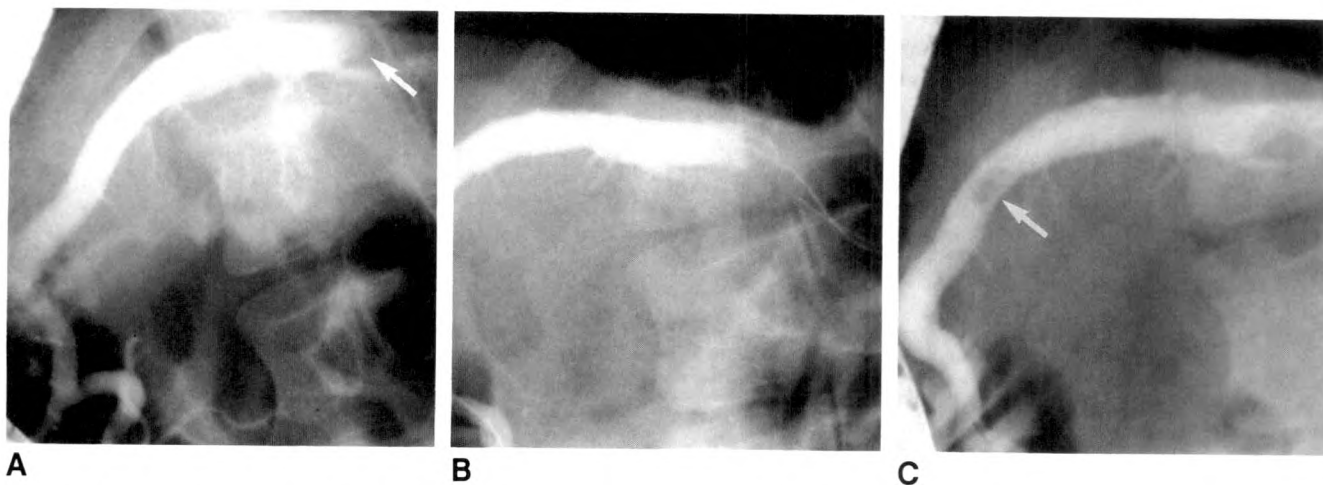


Fig. 6.—Gelatinous cast associated with chronic pancreatitis in 34-year-old man with a 3-year history of chronic pancreatitis.

A, Endoscopic retrograde cholangiogram after initial injection of contrast material into pancreatic duct suggests ductal obstruction (arrow) near junction of body and tail.

B, In an attempt to better define area of cutoff and to ensure adequate filling, a guidewire was passed to advance a catheter near presumed site of obstruction. A radiograph obtained during guidewire placement shows tip of guidewire advancing into more proximal, nonopacified part of duct.

C, Eventually, a balloon tip catheter was placed into nonopacified segment of duct. A radiograph shows part of gelatinous mass being removed (arrow). At subsequent surgery, pancreas had changes of chronic pancreatitis. Pathologic examination of resected pancreatic tail showed no evidence of malignancy.

injection at ERP approximately 70% of the time [1]. Although care must be taken not to overinject the pseudocyst, filling defects due to blood clot or debris can be visualized with contrast material partially filling the cavity (Fig. 8).

Neoplasia

Intraductal filling defects associated with pancreatic neoplasms are unusual. These intraductal foci are related either

to the tumor itself or to the associated secretion of a gelatinous cast.

Benign intraductal masses are rare. The intraductal papilloma is probably the most common benign intraductal tumor (Fig. 9). It may be single or multiple and may be associated with hypersecretion of mucin.

The most common malignant pancreatic tumor, ductal adenocarcinoma, is usually associated with ductal stricture or amputation. However, on occasion, it may appear as an

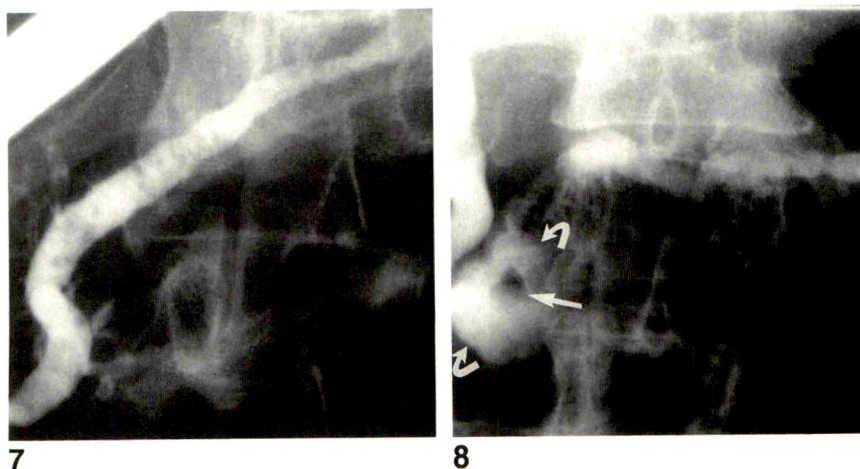


Fig. 7.—Filling defects seen in acute pancreatitis. Endoscopic retrograde cholangiogram of a 27-year-old patient with acute pancreatitis was obtained to check for a gallstone in common bile duct. Contrast material was inadvertently injected into pancreatic duct. This examination shows numerous filling defects that can be associated with acute pancreatitis.

Fig. 8.—Filling defect within a pseudocyst. Endoscopic retrograde pancreatogram shows large, angular filling defect (straight arrow) in pseudocyst (curved arrows), which fills off head of pancreatic duct. Other findings of chronic pancreatitis are seen in more proximal part of duct.

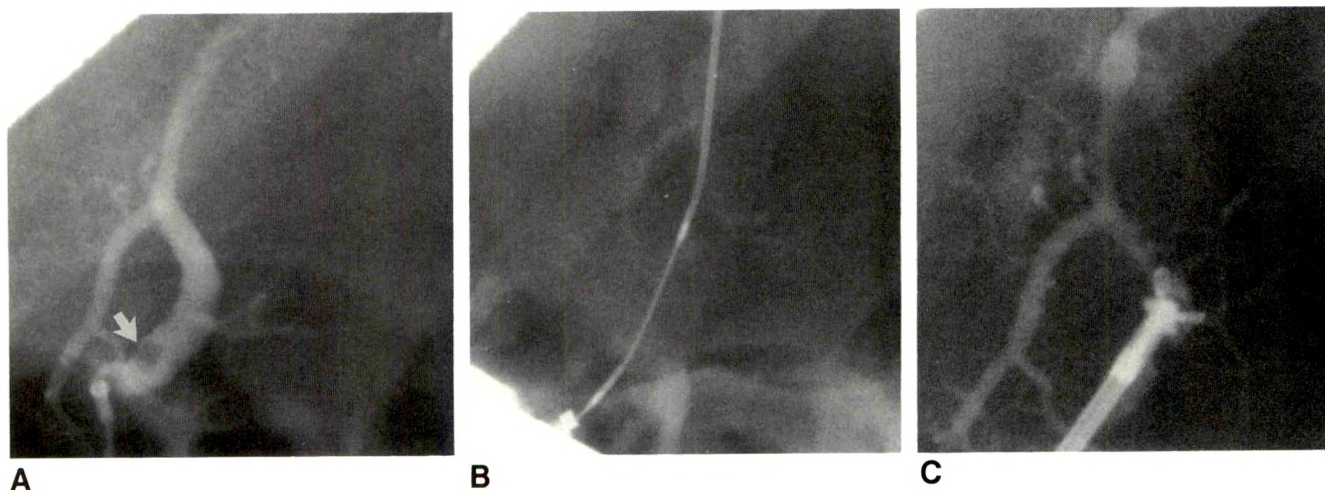


Fig. 9.—Probable benign intraductal papilloma.

A, Initial pancreatogram shows a small, smooth, stationary defect (arrow) in distal part of pancreatic duct. B and C, To further define small mass, a brush biopsy was done (B), and forceps biopsy was attempted (C), during time of initial study. No malignant cells were found. Lack of change seen on endoscopic retrograde pancreatography over 18 months suggests a benign mass compatible with an intraductal papilloma.

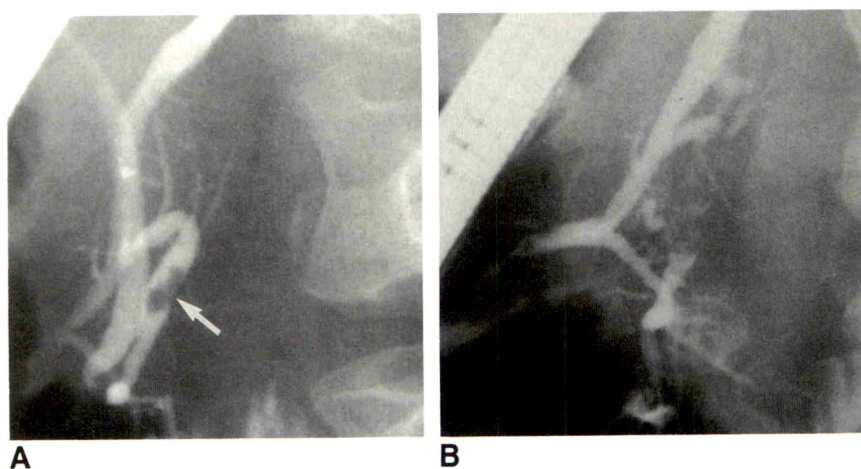


Fig. 10.—Intraductal adenocarcinoma of pancreas.

A, Endoscopic retrograde pancreatogram (ERP) shows a focal, mildly irregular mass (arrow) projecting into pancreatic duct. Results of brush cytology were unrevealing.

B, Follow-up ERP 9 months later reveals enlargement of mass with obliteration of ductal segment. Malignant cells were obtained at this time. Adenocarcinoma was found at surgery.

Fig. 11.—Intraductal adenocarcinoma of pancreas.

A. At endoscopic retrograde pancreatography, injected contrast material courses between filling defects, which expand distal duct. Marked enlargement of duct with immobile filling defects suggests contrast material coursing through crevices of intraductal mass rather than between numerous faceted calculi.

B. Photomicrograph of surgical specimen correlates directly with pancreatogram, showing markedly dilated distal portion of pancreatic duct (arrowheads) and intraductal tumor (straight arrows). Curved arrow points to papilla for orientation. (H and E, original magnification $\times 5$)

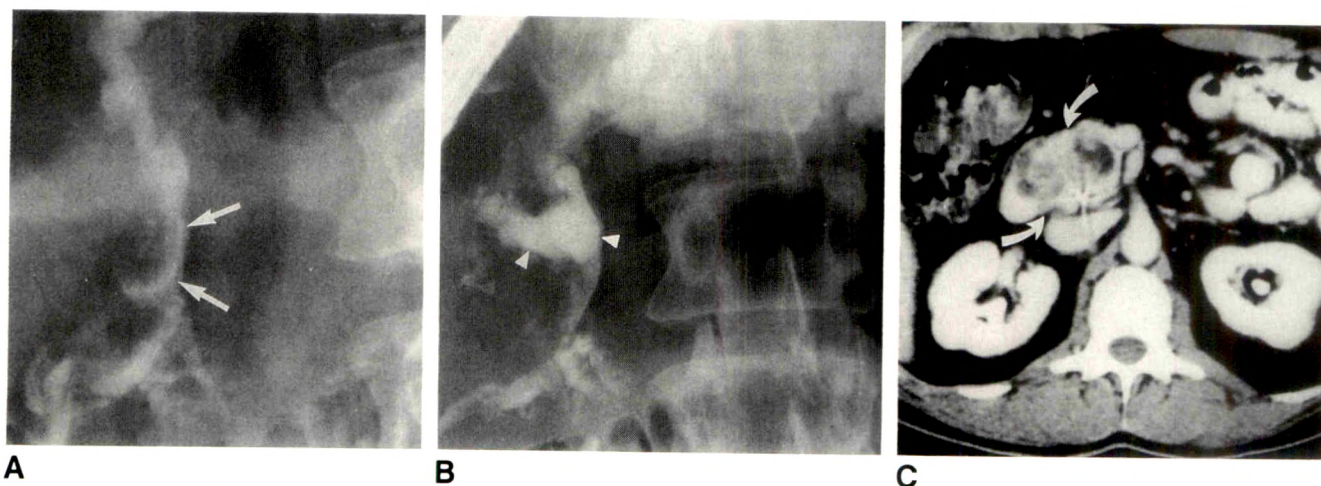
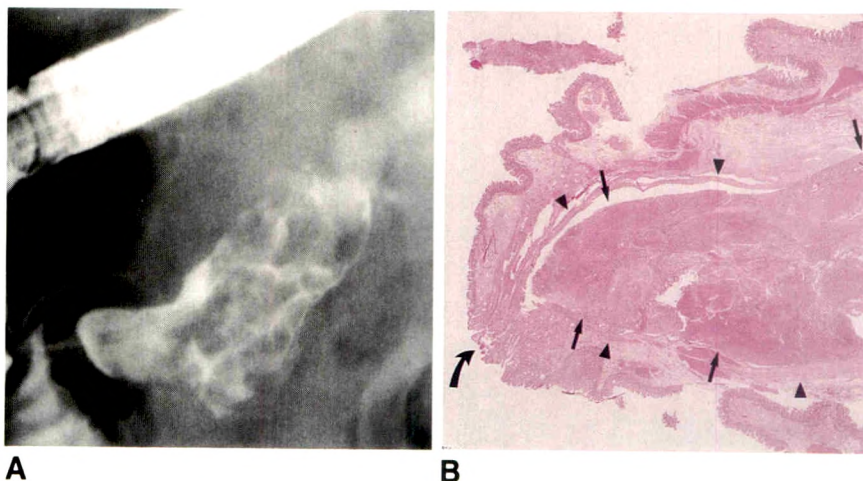


Fig. 12.—Mucinous cystic pancreatic neoplasm.

A. Endoscopic retrograde pancreatogram initially shows a mass (arrows) protruding into pancreatic duct.

B. With further injections, a cavity begins to fill with contrast material (arrowheads). Communication between mucinous cystic neoplasm and main pancreatic duct is unusual.

C. CT scan 1 day later shows multiple cysts with large, solid component in pancreatic head (arrows). Other CT scan helped to better define large cysts of this mass, suggesting a macrocystic cystadenoma or cystadenocarcinoma. At surgery, a mucinous (macrocystic) cystadenocarcinoma was resected.

intraductal filling defect, either as a polypoid mass (Fig. 10), very similar to the intraductal papilloma (compare Figs. 9 and 10), or as a large, irregular growth expanding the main pancreatic duct (Fig. 11). Rarely, adenocarcinoma will occur with mucinous hypersecretion in association with a plaque or polypoid lesion [2].

A mucin-filled pancreatic duct is most often associated with mucinous cystic neoplasms of the pancreas. As with other hypersecretory tumors, the excessive gelatinous material can cause dilatation of the main pancreatic duct with extension into the ampullary segment or even the distal portion of the common bile duct. The associated pancreatic mass may not be visible at ERP, and correlation with CT or sonography is important. However, the cystic mass may be apparent at ERP because of draping, narrowing, or total obstruction of the main pancreatic duct. Some abnormality is seen at ERP in

approximately 60% of cases [3]. As opposed to the inflammatory pseudocyst of pancreatitis, communication between the pancreatic duct and the cystic neoplasm is unusual but does occur (Fig. 12). The serous cystadenoma (microcystic adenoma), the other common cystic neoplasm of the pancreas, rarely shows communication with the pancreatic duct and therefore is not associated with intraductal filling defects. This lack of communication probably is due at least in part to the incomplete network of fibrous strands surrounding the tumor, which separates it from the pancreatic parenchyma. As with mucinous cystic tumors, some mass effect involving the ductal system may be present.

A variation of a mucinous cystic neoplasm is the ductectatic mucinous cystadenoma or cystadenocarcinoma. By far, the most common appearance at ERP is dilatation of the uncinate branch, which is filled with mucinous casts (Fig. 13). Some

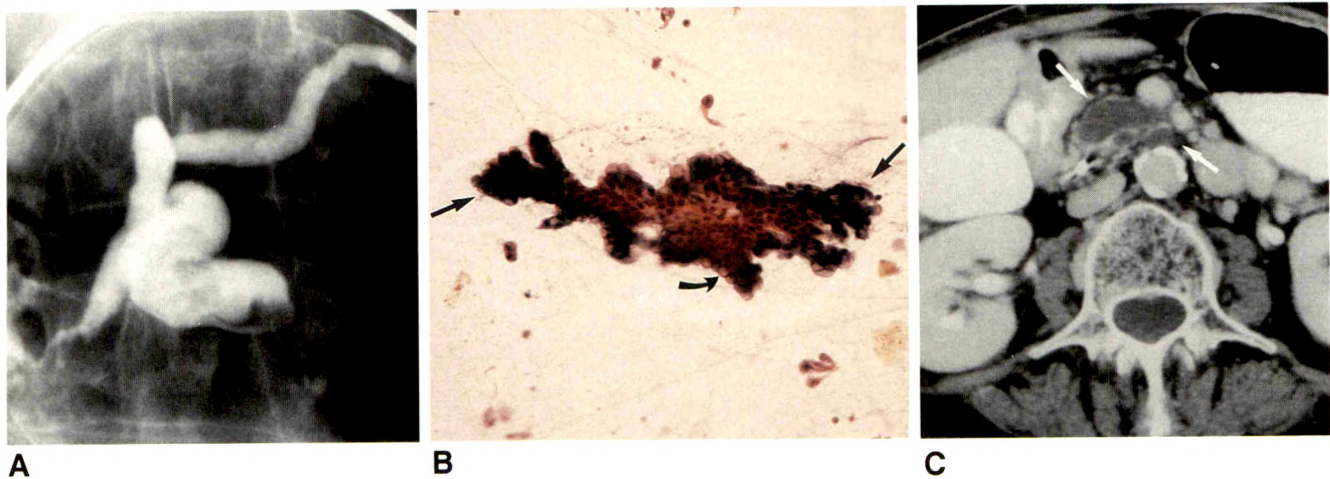


Fig. 13.—Ductectatic mucinous cystadenoma in a 78-year-old woman with abdominal pain.

A, Endoscopic retrograde pancreatogram shows markedly dilated uncinate branch with a long serpentine filling defect. This finding is typical for ductectatic tumors.

B, During endoscopy, some of mucinous cast was obtained and sent for cytologic examination. Photomicrograph shows a fragment of tissue (straight arrows) with papillary excrescences that had been shed into duct. Goblet cells (curved arrow), which produced mucinous cast, are present. Radiologic and pathologic findings suggest a ductectatic mucinous cystadenoma. Of course, because of sampling error, this could still be a malignant lesion. Because of patient's age and health, she was treated with a pancreatic stent. (Papanicolaou's stain, original magnification $\times 400$)

C, CT scan obtained 1 day later shows "cysts" (arrows) in uncinate process of pancreas representing a cross section through markedly dilated uncinate branch of pancreatic duct.

filling defects may be related to small papillary tumors. These dilated ducts are lined by a papillary hyperplastic epithelium that may be atypical or even frankly malignant. The abundant amount of mucus secreted by this epithelium produces the findings at ERP. Retrieval of the mucinous material from the duct during endoscopy can be helpful in providing cells for histologic diagnosis (Fig. 13B).

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Pictorial Essay

Spiral CT of the Pancreas with Multiplanar Display

Elliot K. Fishman,¹ Susan H. Wyatt, Derek R. Ney, Janet E. Kuhlman, and Stanley S. Siegelman

This essay illustrates the findings obtained with spiral CT imaging in pancreatic disease. Features of spiral CT—fast scanning, dynamic injection of contrast material allowing optimal vessel opacification, and supplemental multiplanar imaging—promise to provide increased accuracy in the diagnosis and staging of pancreatic disease. With further development of continuous (spiral/helical) scanning technology, this technology should expand to cover a wider range of applications.

Although the CT technique for pancreatic evaluation varies, several basic principles are universal. Thin-section (4- or 5-mm) scans at narrow interscan increments and dynamic scanning with rapid injection of IV contrast material are critical for optimal detection of pancreatic disease [1].

The recent introduction of spiral or helical scanning, with the capability of obtaining a series of contiguous scans in 24 sec, provides an opportunity to optimize data acquisition for pancreatic evaluation and analysis [2]. Spiral CT has not only the potential of allowing scanning during the phase of maximum vascular enhancement (superior mesenteric artery, superior mesenteric vein, portal vein) but the ability to acquire multiple thin sections through the area of interest during this imaging window. Unlike standard dynamic CT, in which a scan is obtained, there is then table incrementation, and another slice is obtained (usually with a 5–8 sec interscan delay), spiral CT is a continuous acquisition lasting 24 sec. The X-ray tube is continuously on, and the patient travels through the gantry. After all the data are acquired, images are processed. This decreases the scanning time for evalua-

tion of the pancreas from around 4 min to 24 sec. Because spiral scanning creates volumes of data, the information gained can be viewed not only as axial slices but also as multidimensional displays (i.e., coronal and sagittal) [3]. We illustrate the spiral CT findings for pancreatic disease and define the potential role of this technique in the evaluation of the pancreas.

Technique of Examination

During the 30–45 min before their examination, all patients were given 750 ml of oral contrast material (Hypaque 3% in a flavored solution). All scans were done on a commercially available Siemens Somatom-Plus scanner (Siemens Medical Systems, Iselin, NJ) with software version D with the spiral CT option (version 1.1). After a topogram, a single unenhanced scan was obtained to center the image field. A total of 120 ml of IV contrast material, methylglucamine diatrizoate (Hypaque 60) or iohexol (Omnipaque 300) (Sanofi Winthrop Pharmaceuticals, New York, NY), was then injected at a rate of 3 ml/sec. In most cases, contrast material was injected through a peripheral venous access route; in other cases, it was injected through a catheter in the superior mesenteric artery. Data acquisition began 40 sec after the injection of contrast material.

Scanning parameters were 125 kVp and 165 mA with a total slice thickness of 4 or 8 mm. For the spiral protocol, the total scanning time was 24 sec. Patients were instructed to

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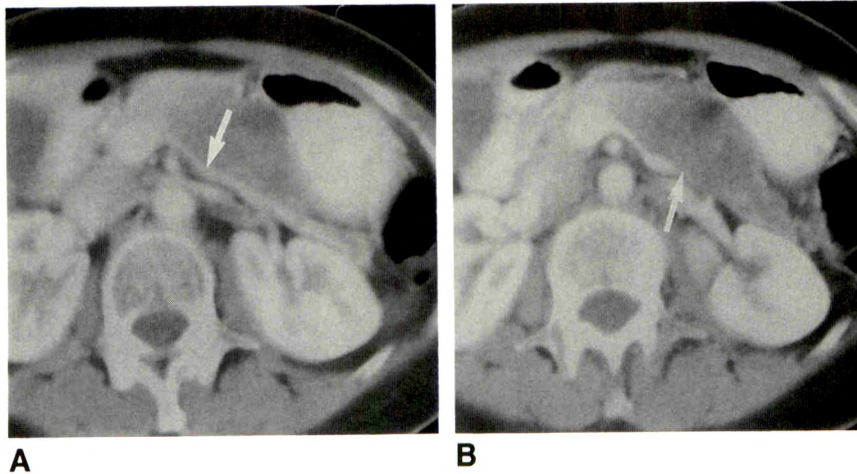


Fig. 1.—Biopsy-proved adenocarcinoma of junction of body and tail of pancreas in a 51-year-old woman with 11-kg weight loss.

A and B, Spiral CT scans show compression and early invasion (arrows) of splenic vein by necrotic pancreatic mass.

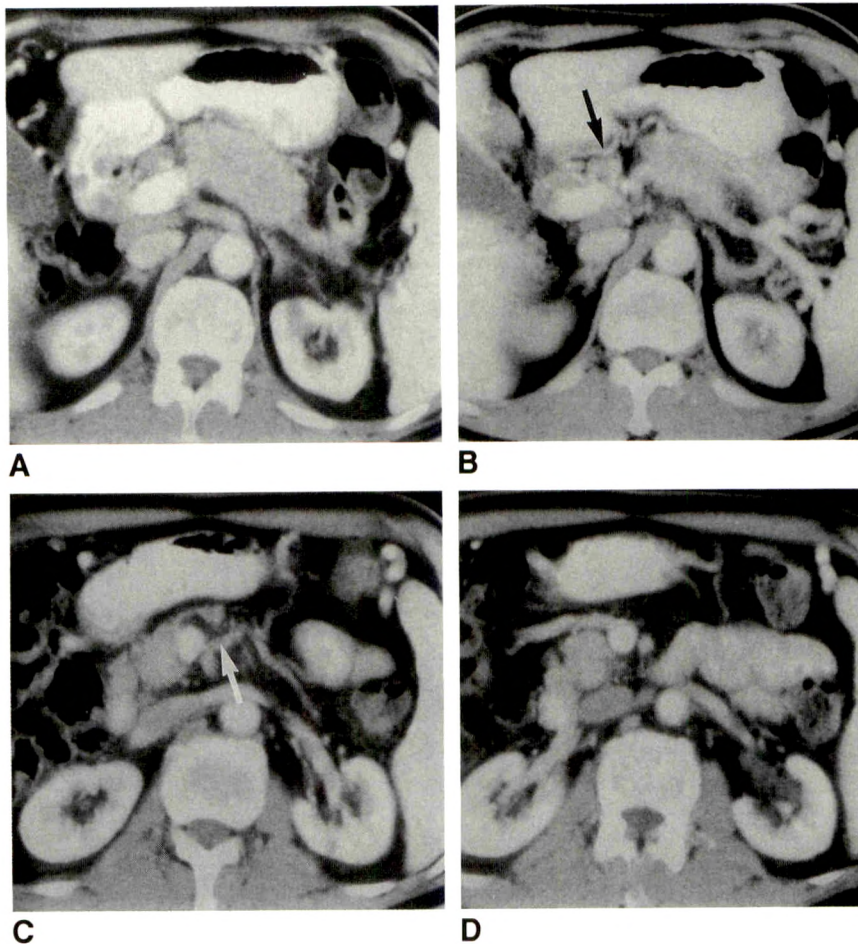


Fig. 2.—Biopsy-proved islet tumor (glucagonoma) of body of pancreas in a 68-year-old man with abdominal pain.

A–D, Spiral CT scans show occlusion of splenic vein and resultant venous collaterals (arrows). Gastrocolic and inferior mesenteric veins are dilated.

hold their breath during the entire study. We routinely had the patient try to hyperventilate just before scanning began because this made it easier for them to hold their breath throughout the study. The spiral protocol used either a table incrementation of 4 mm/sec, 4-mm collimation, and reconstruction at 2-mm intervals or table incrementation of 8 mm/sec, 8-mm collimation, and reconstruction at 4-mm intervals. This re-

sulted in the reconstruction of 48 individual slices with each protocol. When a table incrementation of 4 mm/sec was used, a total of 9.6 cm was scanned; with a table incrementation of 8 mm/sec, a total of 19.2 cm was scanned. The latter protocol was used when the liver (in addition to the pancreas) was to be scanned dynamically.

After acquisition and reconstruction of all scans (recon-

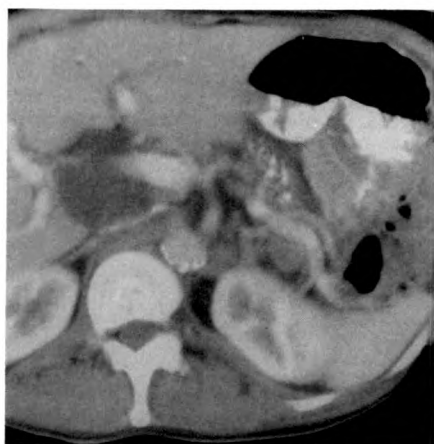
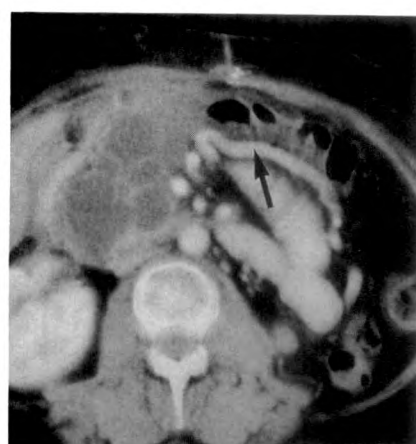


Fig. 3.—Spiral CT scan of 52-year-old man with a history of acute and chronic pancreatitis shows a pseudocyst dissection into porta hepatis. Note displacement and compression of portal vein.



A



B

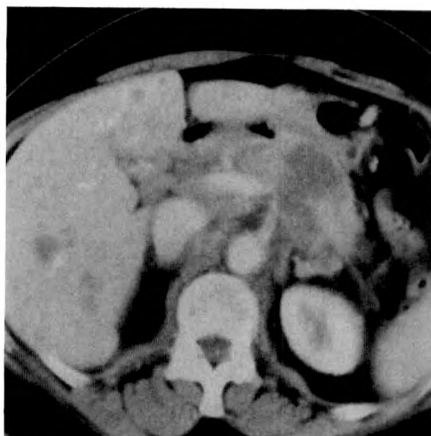
Fig. 4.—Biopsy-proved mucinous cystadenocarcinoma of head of pancreas in a 58-year-old woman with abdominal pain and a history of a pancreatic mass.

A and B, Spiral CT scans show cystic tumor with central calcification in head of pancreas caused by occlusion of portal vein and large collaterals (arrow).

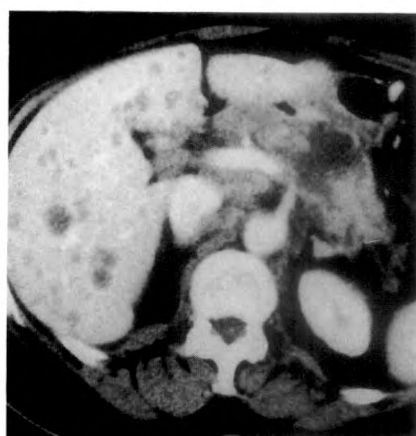
Fig. 5.—Biopsy-proved adenocarcinoma of pancreas in a 52-year-old woman who had abdominal pain and early satiety.

A, Spiral CT scan shows necrotic tumor invading and encasing superior mesenteric artery, superior mesenteric vein, and splenic vein. Multiple small liver metastases also are present.

B, Spiral CT scan with narrow window shows extent of tumor necrosis. Optimal timing of contrast enhancement helps accentuate difference between normal pancreas and tumor.



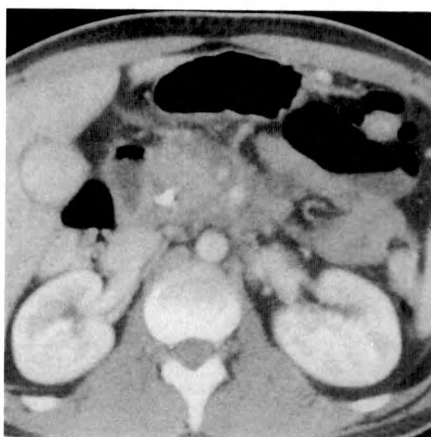
A



B

Fig. 6.—Biopsy-proved large-cell lymphoma in an 18-year-old man with a history of weight loss and abdominal pain.

A and B, Spiral CT scans show diffuse infiltration of pancreas and peripancreatic planes with encasement of superior mesenteric artery and superior mesenteric vein. Note dilatation of gastroduodenal vein (arrow).



A



B

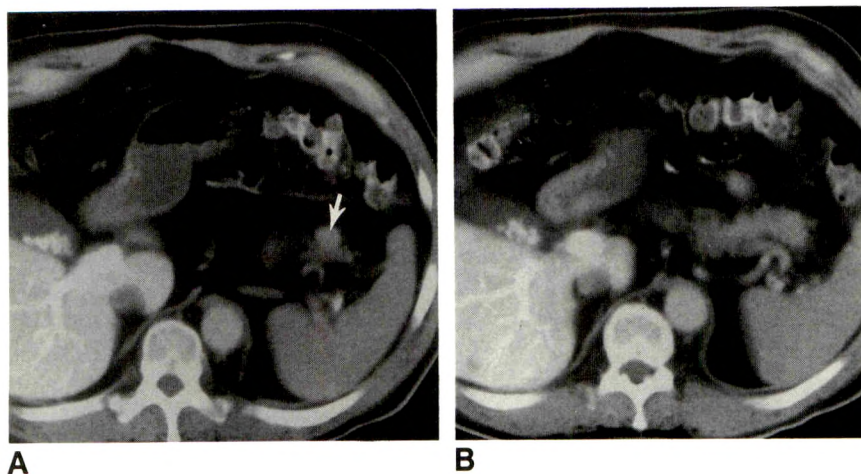


Fig. 7.—55-year-old man with suspected insulinoma.

A and B, Spiral CT scans show 1-cm enhancing lesion (arrow) arising from tail of pancreas. Note that lesion appears to rise off superior pancreatic surface without distorting pancreatic contour or texture.

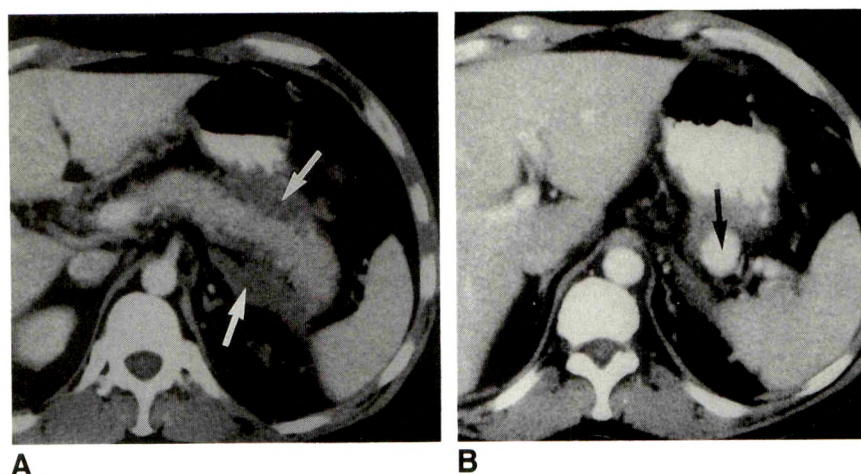


Fig. 8.—53-year-old man with acute pancreatitis.

A, Spiral CT scan through pancreas shows inflammation with adjacent peripancreatic fluid (arrows).

B, Spiral CT scan at level of splenic hilum shows unsuspected pseudoaneurysm of splenic artery (arrow) caused by pancreatitis. Enhancement levels of aorta and aneurysm were nearly equal (252 H).

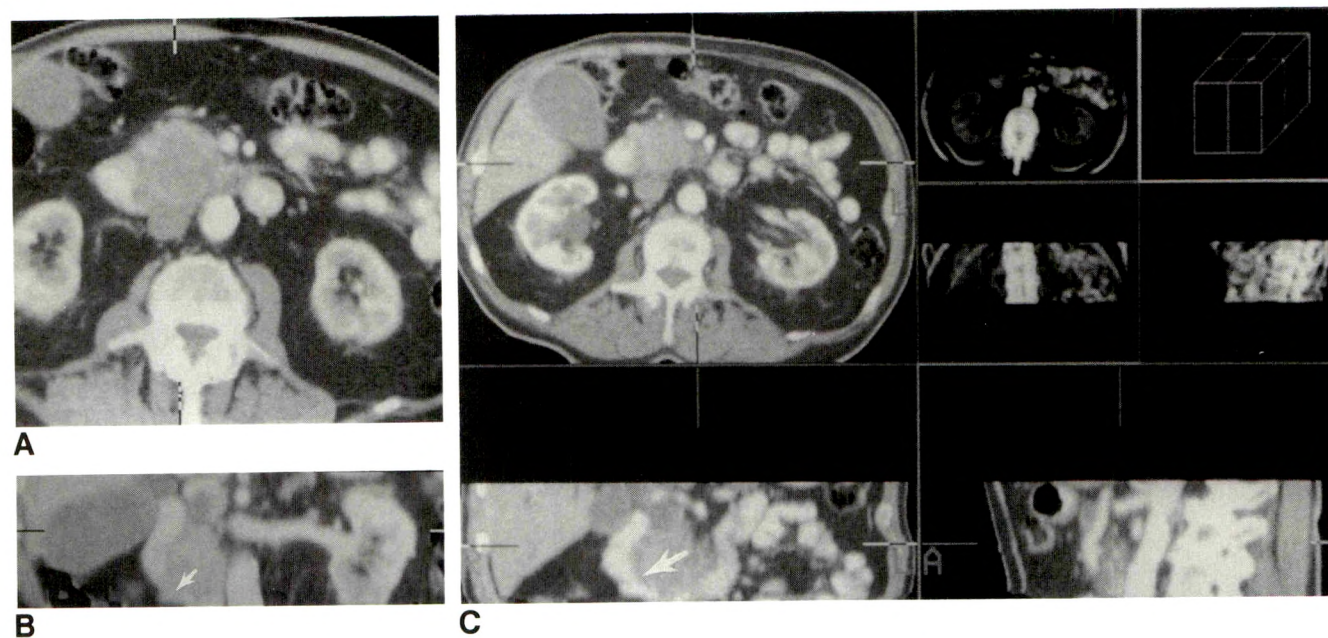


Fig. 9.—Biopsy-proved adenocarcinoma of pancreas in a 65-year-old man who had weight loss and abdominal pain.

A, Spiral CT scan shows 3.5-cm mass in head of pancreas with sparing of superior mesenteric artery and vein.

B and C, Multiplanar display of spiral CT scans show close proximity of tumor to surrounding structures. Coronal views show tumor encompassed within C loop and subtle tumor invasion of duodenal wall (arrows). Tumor was close to superior mesenteric artery, superior mesenteric vein, and inferior vena cava, making resection difficult. Vessels, however, were free of tumor. On sagittal views, axis of superior mesenteric vein is clear with no tumor extension.

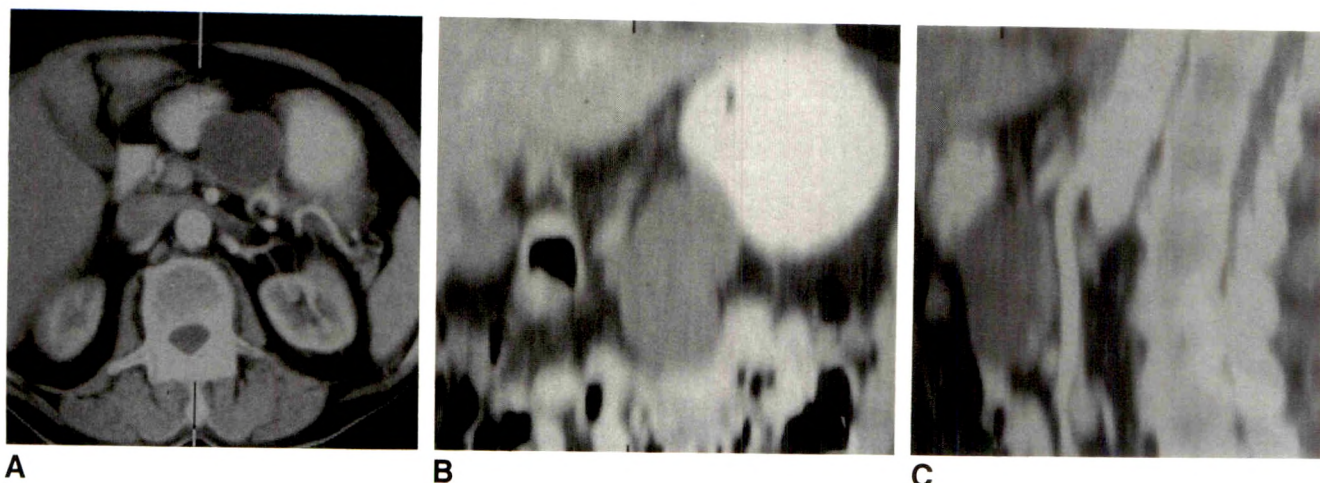


Fig. 10.—Mucinous cystadenoma in a 67-year-old man with palpable epigastric mass.

A, Axial spiral CT scan shows a septated cystic mass arising from body of pancreas.

B, Coronal spiral CT scan shows close apposition of mass to stomach.

C, Sagittal spiral CT scan shows superior mesenteric artery arising from aorta and clearly free of tumor involvement.

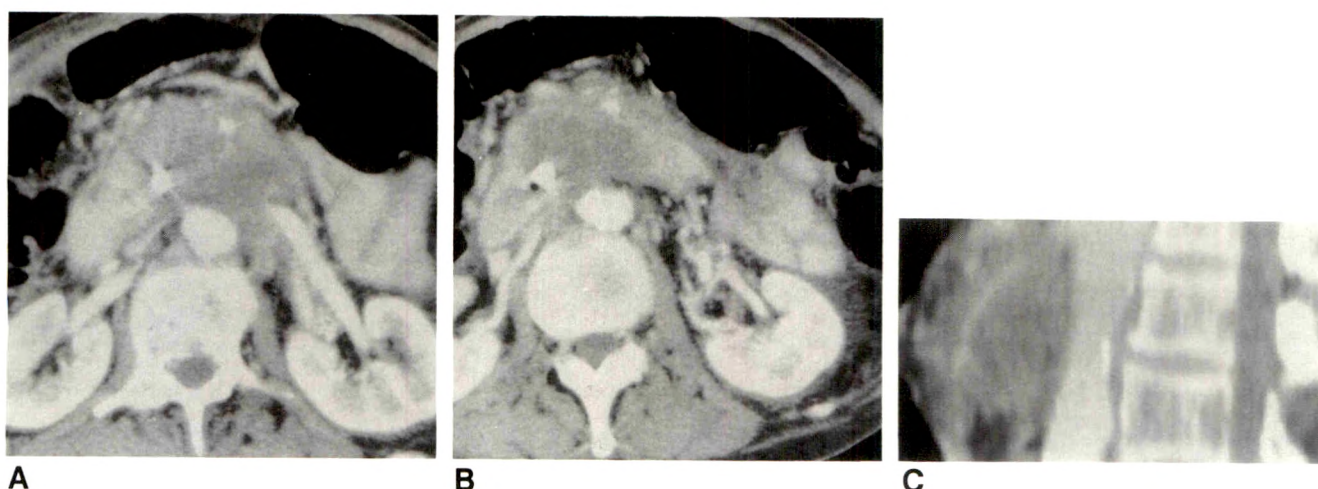


Fig. 11.—68-year-old man with jaundice and biliary catheter in place. Multiplanar sequence of spiral CT scans shows an extensive carcinoma of pancreatic head with extension to and encasement of superior mesenteric artery.

A and B, Axial scans show encasement of left renal vein and collateral vessels.

C, Sagittal projection shows encasement by pancreatic tumor of superior mesenteric artery beginning at artery's origin.

struction time of 6 sec per image), the images were sent via Ethernet to a freestanding workstation for detailed analysis. The workstation consists of a Sun Microsystems Workstation 4-280 or 4-330 (Sun Microsystems, Inc., Mountain View, CA) and a Pixar Image Computer (Vicom, Inc., Fremont, CA). All images were interactively reviewed by using Orthotool [3] (Advanced Medical Imaging Laboratory, Johns Hopkins Hos-

pital, Baltimore, MD) and a bicubic interpolation. Thus, images could be viewed [3] in coronal, sagittal, and oblique planes in order to optimize visualization of the pancreas and adjacent vascular and soft-tissue structures.

All images were then reviewed to determine the presence or absence of pancreatic abnormalities; the cause of any pancreatic abnormality; and the extent of disease, with an emphasis on vascular encasement or invasion (when a neoplasm was suspected).

Discussion

Spiral CT scanning brings to CT a concept that forms the basis for all advanced medical imaging. By scanning an entire area or volume, we are no longer limited to single slices of data; instead, we gain a volume of data [2]. This allows us to



Fig. 12.—Sagittal spiral CT scan shows normal pancreas in a 60-year-old man with weight loss. Compare normal superior mesenteric artery with encasement of superior mesenteric artery seen in Fig. 11.

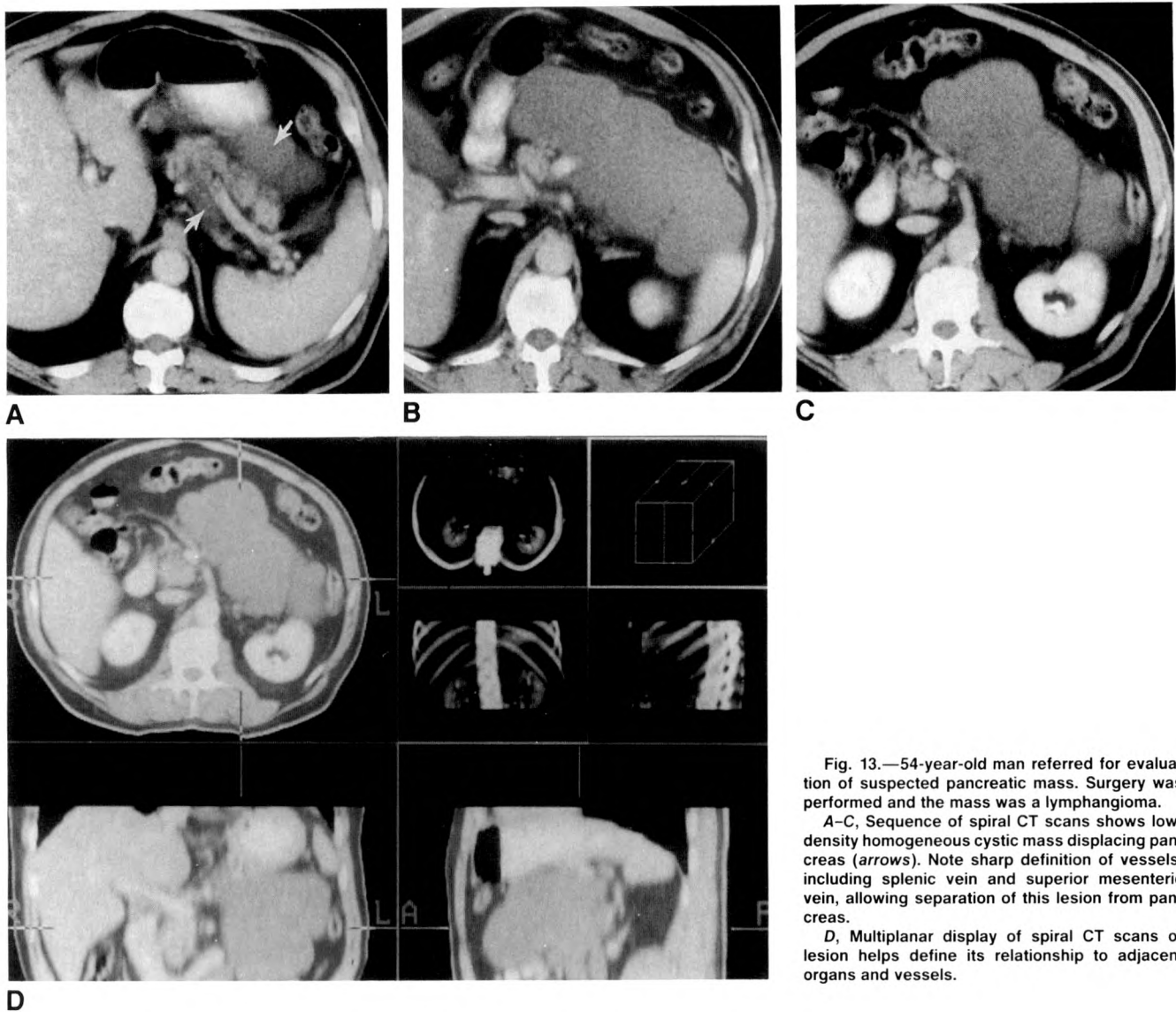


Fig. 13.—54-year-old man referred for evaluation of suspected pancreatic mass. Surgery was performed and the mass was a lymphangioma.

A–C, Sequence of spiral CT scans shows low-density homogeneous cystic mass displacing pancreas (arrows). Note sharp definition of vessels, including splenic vein and superior mesenteric vein, allowing separation of this lesion from pancreas.

D, Multiplanar display of spiral CT scans of lesion helps define its relationship to adjacent organs and vessels.

manipulate and view the additional data in any plane or perspective that may seem of value. Although any data set theoretically can be viewed as a volume (even 8-mm-thick sections obtained at 8-mm intervals), the quality of the reformatting is poor because of "aliasing" and interscan motion. The fact that the study can be done in a single breath-hold provides more accurate data sets without the problem of inadvertent misregistration between slices. The ability to reconstruct the data set at any interscan spacing allows us to obtain quality volume data sets. Faster scanning, with properly timed injection of contrast material, also results in a uniformly high level of contrast material throughout the study, optimizing both arterial and venous opacification [4].

The injection techniques used in this study (120 ml of Hypaque 60 or Omnipaque 300 injected at a rate of 3 ml/sec) combined with the timing of data acquisition (scanning begins 40 sec after the start of injection) places the imaging during the phase of peak enhancement, as defined by Foley [4].

Evaluation of the pancreas would seem to be a natural use for spiral CT scanning. This organ lies deep within the abdominal cavity and has a close relationship to key vascular structures such as the portal, splenic, and superior mesenteric veins; the aorta; and the superior mesenteric artery. Opacification of these structures provides important information both in detecting pancreatic abnormalities and in defining their extent (Figs. 1–8). Although the normal pancreas routinely shows only minimal enhancement, the high contrast levels achieved during spiral CT help accentuate the difference between normal pancreas and tumor (Figs. 5 and 6). In cases of vascular tumors, such as insulinomas, the high level of enhancement should help localize even the smallest lesions (Fig. 7). Complications of pancreatitis such as aneurysms of the splenic or pancreaticoduodenal arteries would be easily detected and recognized (Fig. 8).

One of the potential limitations of our current version of spiral CT is the limit of 24 sec for data acquisition. This means

that if both liver and pancreas must be evaluated, the slice thickness must be 8 mm. Optimal spiral scanning requires that slice thickness and table speed be equal. With 24-sec spiral scanning, 19.2 cm will be scanned. If narrower collimation, such as 4 mm, is used, only 9.6 cm can be scanned. But, this limitation is temporary, with both Siemens and other manufacturers (Toshiba and Philips Medical Systems) promising spiral scanning in the 50–60 sec range during the coming calendar year.

We have previously shown the value of multiformatted data in the evaluation of a number of clinical problems, primarily orthopedic [3]. These techniques are inappropriate for evaluation of the abdomen in most cases because of unequal respiratory effort between adjacent slices and inadvertent motion. Spiral CT scanning, as observed, seems to solve this problem (Figs. 9–13). Additionally, good-quality multiplanar imaging requires the generation of multiple contiguous or overlapping slices. With spiral CT, the user can select the reconstruction spacing in a range from 1 to 10 mm. Thus, in

a protocol with a table incrementation of 4 mm/sec and 4-mm collimation, we can reconstruct up to a total of 96 slices (every 1 mm). We routinely reconstruct at 2-mm intervals, resulting in 4-mm-thick slices every 2 mm. In a previous report, we evaluated scanning parameters for multiplanar reconstruction and found that this was an optimal technique. The reformatted images are especially useful in helping the surgeon to understand complex anatomic relationships and disease extent.

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LIST OF BOOK REVIEWS

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| 1188 | Nonpalpable Breast Cancer. Diagnosis and Management. Hermann G, Schwartz IS, Tartter PI |
| 1216 | Double Contrast Gastrointestinal Radiology, 2nd ed Laufer I, Levine MS |
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Book Review

Double Contrast Gastrointestinal Radiology, 2nd ed. By Igor Laufer and Marc S. Levine. Philadelphia: Saunders, 735 pp., 1992. \$125

The first edition of *Double Contrast Gastrointestinal Radiology*, which is now a classic in the field of double-contrast radiology, served to popularize this technique with clinicians and radiologists. However, with the need to add new information, update radiographs, and references, a new edition has been anxiously awaited. Furthermore, despite the widespread use of double-contrast procedures, many clinicians (and radiologists) are not fully aware of the meticulous attention to technique that is required to take full advantage of the diagnostic range of capabilities of double-contrast radiography. Drs. Laufer and Levine and their eight contributors have done a praiseworthy job in presenting the technique and diagnostic range of double-contrast radiography by using text combined with meticulously chosen and reproduced illustrations.

The contents are divided into 18 chapters and an index. Two new chapters have been added on tumors of the esophagus and stomach, topics that were previously included in the general chapters on the esophagus and stomach. The chapter on radiologic-endoscopic correlation present in the first edition has been omitted in the second edition. This is the only major change I found undesirable. A major improvement is the addition of a full chapter on the pharynx (chapter 4) written by Stephen Rubesin, who has published extensively on the subject.

A detailed comparison of the first and second editions reveals that virtually all the information in the first edition has been retained and expanded. The references are fully updated, and new information is scattered throughout. The illustrations are of superb quality, and the number has been considerably increased. Here are some examples of new segments or illustrations of disease processes contained in the second edition: In chapter 5, "The Esophagus," the use of tube esophagography is shown, the discussion of peptic scarring is ex-

panded, and examples of esophagitis associated with cytomegalovirus infection and use of drugs are given. In chapter 6, "Tumors of the Esophagus," new examples of glycogenic acanthosis, fibrovascular polyp, lymphoma, posttreatment studies, and metastases are shown. In chapter 7, "The Stomach," new examples of changes related to use of aspirin and antiinflammatory drugs are given. In chapter 11, "The Small Bowel," a discussion on AIDS and the toxic effects of 5-fluorouracil has been added.

The need for excellent technique is stressed throughout. Methods of performing double-contrast examinations are well covered for all segments of the gastrointestinal tract and the pharynx. In chapter 3, the helpful Problems and Pitfalls section has been expanded.

The overall packaging of the contents is extremely aesthetic and readable. Each chapter begins with a detailed outline, which is useful for quick reference. The typeface and type size are excellent. The reproduction of the radiographs is exemplary (which is no mean feat with double-contrast films). A new feature is the occasional use of comparison CT scans.

No truly comparable texts are on the market. Although many introductory texts are available to choose from, I think that this text is unique and should be required reading for all radiologists who perform and interpret gastrointestinal studies. My only major criticism of the new edition is the removal of the color photographs of endoscopic correlation (which were probably expensive to reproduce). Inasmuch as the cost of reproducing radiologic images is high, this text (with more than 730 illustrations) is a bargain.

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Rupture of the Bowel After Blunt Abdominal Trauma: Diagnosis with CT

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David R. Gens²
Kathirkamanathan Shanmuganathan¹

OBJECTIVE. The accuracy of CT in the detection of injuries of the solid viscera after blunt trauma is well established, but the value of CT in diagnosing bowel rupture resulting from blunt trauma is controversial. This study was conducted to determine the sensitivity of CT in diagnosing posttraumatic bowel rupture.

SUBJECTS AND METHODS. During a 51-month period, 17 preoperative CT scans were obtained in 16 patients who subsequently had bowel ruptures verified surgically. Both preoperative (prospective) and retrospective CT findings were analyzed in these patients. Retrospective interpretation was made by consensus of two radiologists.

RESULTS. Surgically confirmed bowel ruptures occurred in the duodenum (five), ileum (four), jejunum (four), colon (four), and stomach (two). CT findings considered diagnostic of bowel perforation were detected prospectively on 10 (59%) of 17 scans; these included pneumoperitoneum without prior peritoneal lavage (six), mesenteric, intramural, or retroperitoneal free air (six), or direct visualization of discontinuity of the bowel wall or extravasation of luminal contents (four). Prospective CT findings considered suggestive of bowel rupture were present on five (29%) of the 17 scans; these included intraperitoneal fluid of unknown source (three), thickened (>4–5 mm) bowel wall (two), gross anterior pararenal fluid without a recognized source (one), and a mesenteric-bowel wall hematoma (one). On two of 17 scans, findings were seen in retrospect only; these included free intraperitoneal blood without a source (findings on a second CT scan were diagnostic) and pneumoperitoneum. CT findings diagnostic or suggestive of bowel injury were detected prospectively on 15 (88%) of 17 scans and were noted in all retrospectively.

CONCLUSION. CT is sensitive for the diagnosis of bowel rupture resulting from blunt trauma, but careful inspection and technique are required to detect often subtle findings.

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The sensitivity of CT in the detection of bowel rupture remains to be established. Numerous earlier studies [1–6] found poor sensitivity of CT for detection of bowel injuries; others [7, 8] have claimed high sensitivity of CT for diagnosing bowel injuries and for distinguishing those bowel injuries that are likely to require surgical intervention. The discrepancy in these observations may arise from the type of study (prospective vs retrospective interpretation), the sophistication of the CT equipment used, the expertise of the interpreters, the types of bowel or mesenteric injuries evaluated in the study (e.g., bowel rupture, serosal tear, mesenteric injury, ischemic injury, bowel wall contusion), the oral administration of contrast material or the lack thereof, and the performance of diagnostic peritoneal lavage before CT.

In light of this controversy, we analyzed both prospective and retrospective interpretation of CT scans of patients with surgically proved bowel rupture identified from our trauma registry [9].

Subjects and Methods

During a 51-month period, from July 1987 to October 1991, 48 patients had surgically confirmed bowel rupture resulting from blunt abdominal trauma that required surgical resec-

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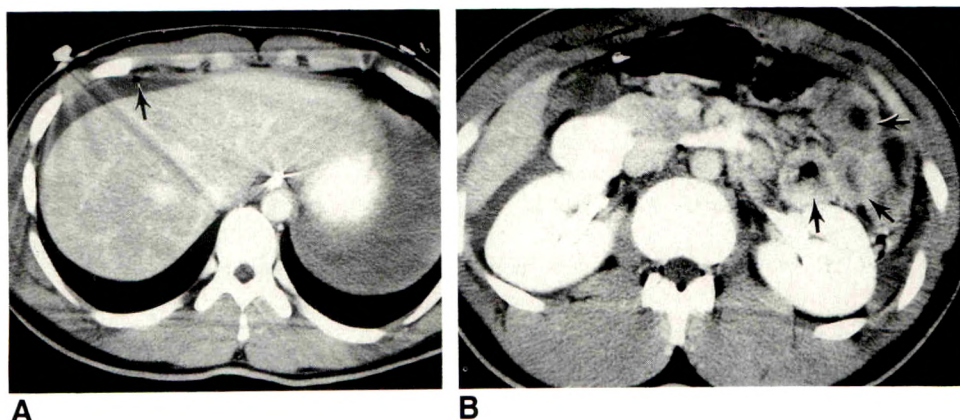


Fig. 1.—Jejunal perforation in 17-year-old involved in motorcycle accident.

A, CT scan shows intraperitoneal fluid below diaphragm on both sides and minimal pneumoperitoneum (arrows).

B, CT scan through mid abdomen shows intraperitoneal free fluid and markedly thickened loops of proximal portion of small bowel (arrows). Jejunal transection was confirmed at surgery.

(Reprinted with permission from Mirvis and Shanmuganathan [10].)

tion. Patients with ischemic bowel, degloving bowel injuries (avulsion of the serosa), or isolated mesenteric injuries were not included in this study. Among these 48 patients, 16 (33%) had preoperative CT, which was performed before diagnostic peritoneal lavage in all cases. These 16 included 14 men and two women 16–50 years old (mean, 26 years). Mechanisms of injury included automobile accidents (11), motorcycle accidents (two), and crushing injuries (three).

CT scans were obtained by using a Siemens DRH (July 1987 to March 1990) with a routine 3-sec scan time or a Siemens Hi-Q (March 1990 to October 1991) with a routine 2-sec scan time (Siemens Medical Systems, Iselin, NJ). Most of the preoperative CT scans (14) were obtained with the Hi-Q scanner later in the study because of a generalized increase in the use of CT for evaluation of abdominal trauma during this period and because of the proximity of the scanner to the area where patients were admitted. All patients received oral contrast material consisting of 5 g of Hypaque powder (Winthrop Pharmaceuticals, New York, NY) or 10 ml of 37% Gastrografin (Squibb Diagnostics, Princeton, NJ) in 10 oz (300 ml) of water 30–45 min before the scan and a second dose either orally or by nasogastric tube when they arrived at the scanning suite. Contrast material was not administered rectally in these cases. When the DRH scanner was used, contrast material was given IV as a hand-injected bolus of 100 ml of 60% Renografin (Squibb Diagnostics) before scanning; this was followed by a drip infusion of 30% contrast material (average, 200 ml). When the Hi-Q scanner was used, contrast material was given IV as a power-injected bolus of 100 ml of 60% Hypaque (at 2 ml/sec) before scanning; this was followed by an infusion of an additional 50–100 ml of 60% contrast material at a rate of 0.7–1.0 ml/sec. Preoperative interpretations of the CT scans were compared with surgical findings. In addition, CT scans were reviewed by two of the authors in all surgically proved cases of ruptured bowel, and CT findings were compared with the initial interpretations and surgical findings.

Results

Nineteen surgically confirmed bowel ruptures were detected: five to the duodenum, four to the jejunum, four to the ileum, four to the colon, and two to the stomach. Preoperative CT findings considered diagnostic of bowel rupture were noted in 10 (63%) of these 16 patients. These included pneumoperitoneum without an intrathoracic source or previous peritoneal lavage in six (Fig. 1) [10]; extraperitoneal gas in the mesentery (Fig. 2), bowel wall (Fig. 3) [11], or retroperitoneum (Fig. 4) in six; and direct visualization of bowel

wall discontinuity in three (Fig. 5), with extraluminal extravasation of contrast material (Fig. 2) or feces (Fig. 4). Many additional supporting findings were observed in these 10 patients. These included bowel wall thickening in four (Fig. 1), free intraperitoneal fluid in four (Figs. 1 and 3), and anterior pararenal or intramesenteric fluid in three (Figs. 2 and 5).

CT findings regarded as suggestive of bowel rupture were noted in another five of the 17 scans on prospective interpretation, including diffuse thickening of the bowel wall in two (Fig. 6), gross anterior pararenal fluid without a known source in two (Fig. 7), and transmural bowel wall hematoma in one (Fig. 8). Two findings were not made on prospective interpretation but were found retrospectively. One patient had minimal free pelvic fluid of low attenuation without a recognized source; a subsequent preoperative CT scan obtained 44 hr after the initial study, because of the patient's increasing abdominal pain and fever, showed findings diagnostic of bowel injury, including pneumoperitoneum and free intraperitoneal fluid (Fig. 9). Initially missed CT findings in another patient included pneumoperitoneum and perigastric omental gas. This patient had several obvious major injuries of the solid viscera that necessitated urgent laparotomy. Overall, diagnostic or suggestive findings of bowel rupture were observed prospectively in 15 (88%) of 17 CT studies and in all cases retrospectively. None of the patients who were examined by CT for blunt abdominal trauma during the study (2237 scans obtained) and who had CT findings that were diagnostic of bowel rupture were successfully managed without surgery, and in all these cases bowel rupture was verified surgically.

Discussion

Several studies on the accuracy of CT for detecting bowel rupture in patients undergoing exploratory laparotomy have reported poor sensitivity. Cook et al. [6] evaluated CT results in 83 patients with upper abdominal trauma. In three patients with surgically proved small-bowel perforation, the injury was missed on CT, although in one who had duodenal injury, CT findings indicating perforation were seen retrospectively. Two of these 83 patients, in whom CT findings suggested duodenal rupture, had no injury found during surgery (false-positive). In a subsequent report, Hofer and Cohen [12]



Fig. 2.—Duodenal perforation in 28-year-old woman after motor vehicle accident.

A, CT scan through mid abdomen shows extravasation of contrast material posterior to third portion of duodenum (arrows).

B, A more caudal CT scan shows one large and several small irregular gas collections in mesentery, fluid dissecting into mesentery, and fluid-filled distended small bowel.

C, CT scan through upper pelvis shows still further caudal dissection of mesenteric gas (arrow).

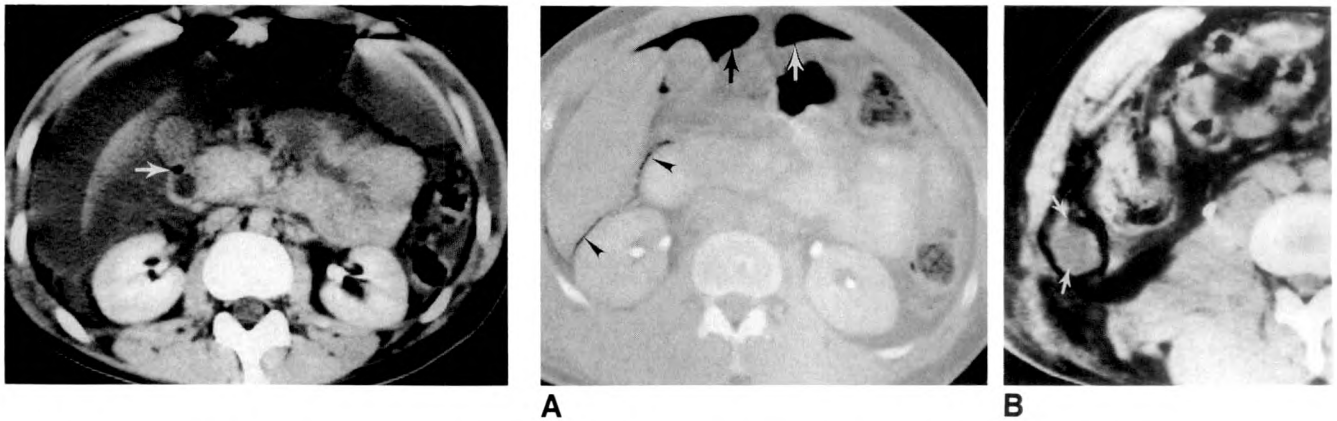


Fig. 3.—Duodenal rupture in a 16-year-old with blunt trauma. CT scan shows thickening of duodenal wall and a dot of gas in wall (arrow). Gas extends into wall of gallbladder. Gross intraperitoneal free fluid and pneumoperitoneum are seen. (Reprinted with permission from Mirvis and Dunham [11]. © 1992, the Williams & Wilkins Co., Baltimore.)

Fig. 4.—Cecal perforation in a 40-year-old who sustained crushing injury. A, CT scan through upper abdomen shows retroperitoneal gas (arrowheads) and pneumoperitoneum (arrows).

B, CT scan through lower abdomen shows disruption of cecum, with extrusion of feces into right pericolic gutter (arrows). Cecal perforation was confirmed surgically.

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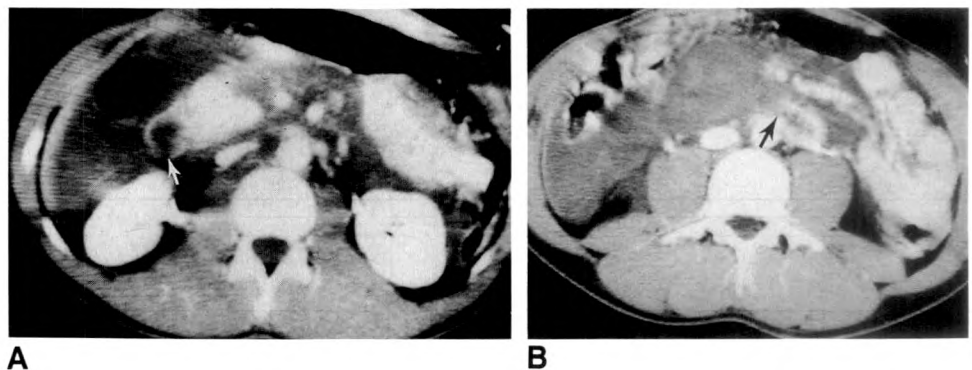


Fig. 5.—Duodenal disruption in 18-year-old man involved in motor vehicle collision.

A, CT scan through mid abdomen shows perforation of posterior duodenal wall (arrow) and obvious fluid in anterior pararenal space.

B, More caudal CT scan shows marked extravasation of fluid in anterior pararenal space and abrupt interruption in continuity of third portion of duodenum (arrow). Perforations of second and third portions of duodenum were surgically confirmed.

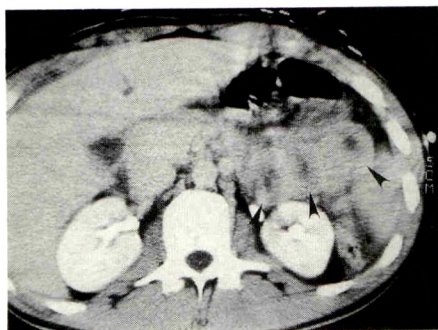
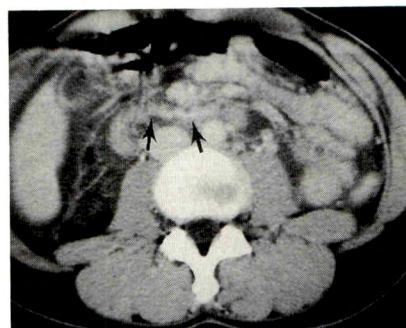
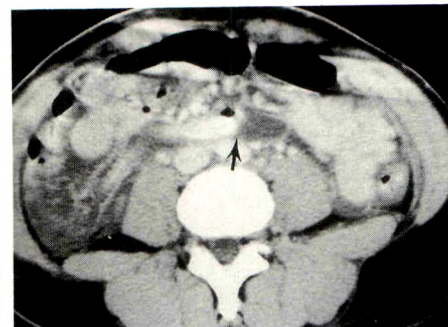


Fig. 6.—Possible jejunal rupture in a 17-year-old after crushing injury. CT scan shows marked thickening of proximal jejunum (arrowheads). Some free intraperitoneal fluid (not shown) also was observed. Proximal jejunal rupture was found at surgery. (Reprinted with permission from Mirvis and Dunham [11]. © 1992, the Williams & Wilkins Co., Baltimore.)



A



B

Fig. 7.—Possible duodenal rupture in 32-year-old woman involved in motor vehicle collision. A, CT scan shows marked retroperitoneal (anterior pararenal) fluid and narrowing of third portion of duodenum (arrows). Some intraperitoneal fluid is present. B, More caudal CT scan suggests abrupt interruption of third portion of duodenum (arrow). At surgery, ruptures of second and third portions of duodenum were found. (Reprinted with permission from Mirvis and Dunham [11]. © 1992, the Williams & Wilkins Co., Baltimore.)

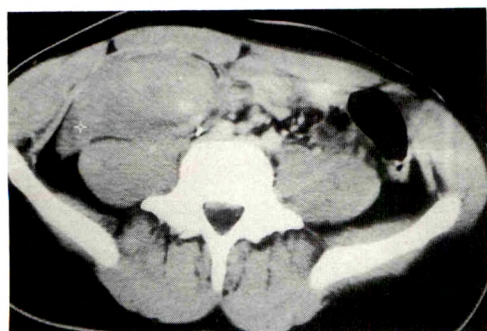
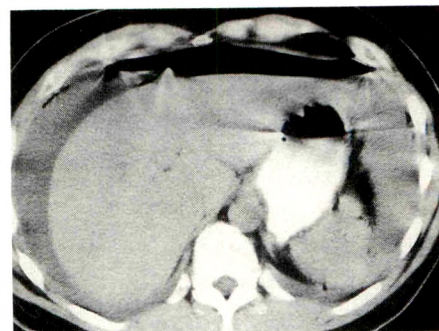


Fig. 8.—Possible bowel rupture in a 20-year-old after motor vehicle collision. CT scan shows large heterogeneous mass in right lower quadrant of abdomen. Diagnostic considerations included bowel or mesenteric hematoma. At surgery, a large cecal transmural hematoma and perforation of ascending colon were found, which required segmental resection. (Reprinted with permission from Mirvis and Dunham [11]. © 1992, the Williams & Wilkins Co., Baltimore.)



A



B

Fig. 9.—Delayed diagnosis of bowel perforation in 50-year-old injured in a motorcycle accident.

A, Initially findings on CT scan were interpreted as normal. On retrospective review, a small amount of free intraperitoneal fluid (arrow) was recognized in pelvis.

B, CT scan obtained 2 days after A, because patient had abdominal pain and fever, shows marked pneumoperitoneum and free intraperitoneal fluid. At surgery, a ruptured jejunum was diagnosed.

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described CT findings in two patients with duodenal perforation, including free intraperitoneal or extraperitoneal gas, extravasation of opacified oral contrast material into the right pararenal space, focal thickening of the duodenum in its midportion that prevented passage of contrast material, and high-attenuation intramural duodenal hematoma.

Two retrospective series on the accuracy of CT in detecting bowel injuries have been reported. Both series were derived from the experience at the San Francisco General Hospital and include data from overlapping periods [7, 8]. The larger series by Rizzo et al. [8] includes a retrospective review of 51 patients in whom CT findings suggested bowel or mesenteric injuries and compares CT findings with surgical outcome. In this series, CT showed evidence of significant bowel injury in 26 (93%) of 28 patients whose injuries were con-

firmed at surgery. These authors compared CT findings indicative of bowel injury between 32 patients who underwent celiotomy and 19 who were managed by observation. Although some overlap of CT findings occurred, patients undergoing laparotomy had a higher prevalence of pneumoperitoneum (32%), free intraperitoneal fluid (96%), and associated injuries (43%) than did patients managed nonoperatively (0%, 21%, and 5%, respectively). Rizzo et al. [8] emphasized the value of CT in detecting signs of bowel and mesenteric injury and in distinguishing injuries requiring surgery from those that do not. Unfortunately, that study was a retrospective review, and the influence of the CT findings of potential bowel injury on the decision to proceed to laparotomy cannot be ascertained.

Although our study included fewer patients, it was a pro-

spective evaluation of CT for the detection of bowel rupture. We compared CT findings with surgical results specifically in patients with bowel rupture and did not assess the accuracy of CT for diagnosing bowel ischemia related to blunt trauma, avulsion of the serosa, or bowel wall contusion. Our results support those of Donahue et al. [7] and Rizzo et al. [8] in that CT accurately showed bowel rupture in 10 of 16 patients and suggested major bowel injury in five others. Significant findings on two CT scans obtained at admission were missed prospectively but were observed retrospectively.

Our results support the value of CT for showing findings diagnostic of bowel rupture, including pneumoperitoneum without prior diagnostic peritoneal lavage; discontinuity of the bowel wall; extravasation of contrast materials; and ectopic gas in the retroperitoneum, bowel wall, and mesentery in patients with bowel transection from blunt impact. We believe the diagnosis of bowel rupture can be aided considerably by oral administration of contrast material, and we encourage its use for CT evaluation of blunt abdominal trauma. We did not encounter any complications related to oral administration of contrast material during this study.

CT findings suggestive of bowel rupture, including thickening of the bowel wall, free fluid in the anterior pararenal space, and intraperitoneal blood or fluid without an obvious source should mandate close scrutiny of findings on physical examination, possibly combined with interval peritoneal lavage or additional CT scans. In many of our patients, the CT findings in bowel rupture were subtle, and detection required careful inspection of scans. Meticulous attention to scanning technique, including reduction of artifacts, optimal bowel con-

trast, and appropriate review of images optimized for detection of minimal pneumoperitoneum will improve sensitivity of CT for diagnosis of bowel rupture.

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Replacement of Nasogastric Suction by Retrograde Jejuno gastric Tube Drainage in the Management of Esophagogastric Complications

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Patients who have complicated postoperative courses after esophagogastric resection [1] can survive longer if drains are inserted promptly [2]. Some patients for whom percutaneous gastrostomy is unsuitable because of previous gastric pull-up operations or total or subtotal gastrectomy may require long-term nasogastric drainage because of anastomotic leakage, postoperative stricture, or bowel paresis. In such cases, long-term indwelling nasogastric tubes necessary for aspiration of esophagogastric fluids are difficult to maintain, and sinusitis, soreness of the nasopharynx, and often intolerable dysphagia may develop. Esophageal strictures caused by esophageal reflux may be exacerbated by long-term intubation [3].

In five patients who were unable to tolerate long-term nasogastric suction after major gastric surgery for tumor and in one patient with proximal jejunal stricture, we were able to replace the nasogastric tube with a functionally equivalent jejuno gastric or jejuno esophageal drain catheter by introducing the catheter in a retrograde manner from an existing or fresh jejunostomy site (Fig. 1), a technique that has not been previously described.

Materials and Methods

We treated six patients who required long-term esophagogastric or jejunal drainage because of postoperative anastomotic esopha-

gogastric leakage, outlet strictures, gastric atony, or reflux esophagitis. Three of these patients had had surgery for gastric cancer, two for esophageal cancer, and one for gastric leiomyoma. They could not tolerate further use of the nasogastric tube because of marked soreness of the nose and throat or because the tube was ineffective. Drainage by percutaneous gastrostomy was not feasible because all the patients had previously had a complete or partial gastrectomy or a gastric pull-up operation. The patients were all fed through a surgically placed jejunal tube. The patients survived 1–6 months after the nasogastric tube was replaced with a retrograde jejuno gastric drain. The course of one patient is typical of the group and illustrates the usefulness and success of retrograde jejuno gastric intubation as an alternative route for chronic gastroesophageal suction.

Representative Case Report

A 57-year-old man had a gastrectomy and then an esophagogastric resection and a splenectomy because of gastric carcinoma. A feeding jejunostomy was created at the time of surgery. After radiotherapy and chemotherapy, he was unable to tolerate oral food intake or tubal feeding owing to recurrent tumor at the anastomotic site. Later in the patient's hospital course, he was unable to tolerate his own secretions and required a permanent nasogastric tube for drainage. A few weeks later, the patient developed such intense nasopharyngeal soreness from the tube that he insisted that it be removed. A retrograde approach through the inlying jejunostomy site was used to insert a

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12-French nasogastric tube. The tube was advanced until its tip was in the distal esophagus above the site of tumor recurrence; the transnasal tube was then removed. Continued and adequate drainage of nasopharyngeal secretions was well tolerated through this new access route. A new retrograde 16-French sump tube was inserted over a stiff guidewire 3 months later. The patient survived another 2 months.

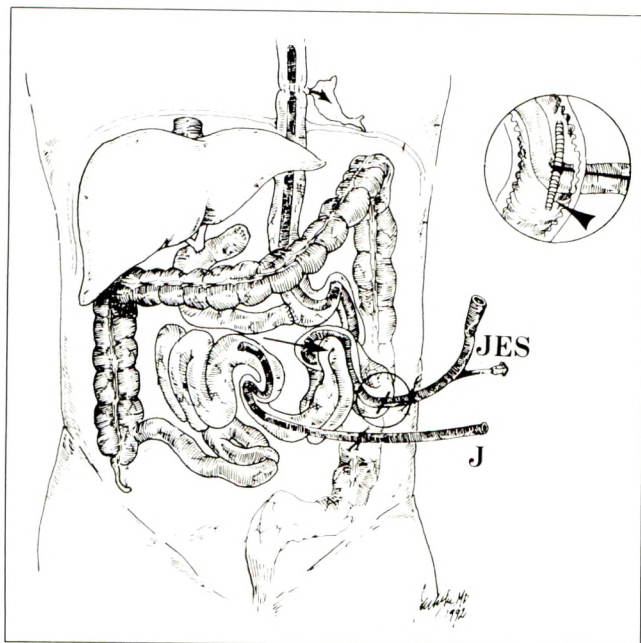


Fig. 1.—Drawing shows technique for retrograde jejunal drainage in a typical patient with an esophagojejunal anastomotic leak. A jejunoesophageal sump catheter (JES) is inserted by percutaneous technique; the catheter cannot be advanced cephalad from the surgical feeding jejunostomy site (J) because of an intervening bowel stricture (arrow). Inset shows anchor device (arrowhead) used to stabilize jejunal loop during insertion of percutaneous drain.

Technique

In all patients, anatomic delineation of the small bowel, gastric remnants, and anastomotic connections were determined with barium studies before the intervention. In order to prevent accidental puncture of the colon if a percutaneous jejunostomy procedure was being considered, the course of the colon was also carefully evaluated by using contrast material. Broad-spectrum antibiotics were administered to all patients. Patients were given IV sedation and their vital signs carefully monitored throughout all procedures, owing to their debilitated state. Four patients required more than one visit to the angiography section for completion of catheter positioning for optimal drainage.

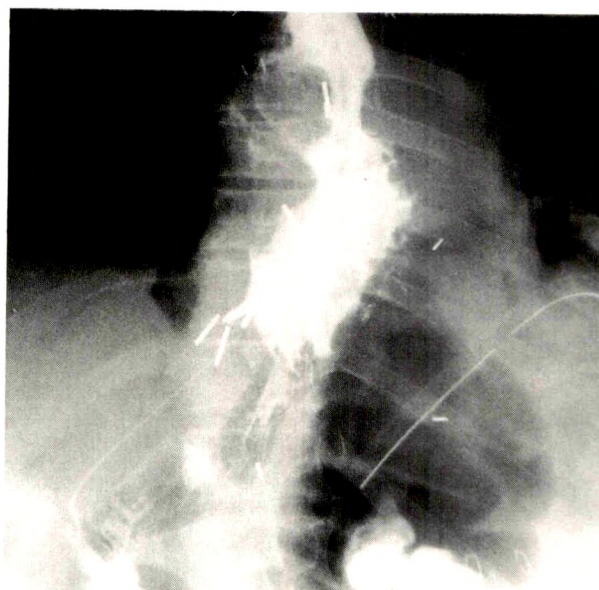
In three cases, the surgical jejunostomy site was successfully used for retrograde placement of the jejunogastric tube. In two other cases, it was not possible to advance a catheter more than 10–20 cm beyond the jejunostomy site toward the esophagus because of acute bowel angulations caused by operative adhesions or tumor. In these cases, a new, more proximal jejunostomy was created percutaneously after opacifying the bowel from the existing jejunostomy (Fig. 1).

In the last case, although a jejunogastric tube was initially successfully inserted through the surgical jejunostomy, it became kinked along its course because of multiple acute bowel angulations and had to be replaced through a more proximal percutaneous jejunostomy site.

Percutaneous jejunostomy is performed as follows. An unaffected jejunal loop, which is opacified retrogradely via the existing jejunostomy site, is punctured with a 21-gauge needle under fluoroscopic guidance, and the jejunostomy tract is serially dilated to 16- or 18-French. If the loop of small bowel chosen is freely movable, it is first attached to the abdominal wall with a suture anchor device (Cook, Inc., Bloomington, IN) delivered through a 17-gauge needle to prevent invagination, before the jejunostomy tract is dilated.

Fig. 2.—A, Contrast-enhanced radiograph shows a high esophagogastric anastomosis following a gastric pull-up operation for esophageal carcinoma with an inlying 18-French nasogastric drain. The patient had reflux esophagitis and severe dysphagia.

B, Radiograph shows nasogastric suction tube has been replaced by a 16-French retrograde sump, which was inserted percutaneously through a jejunal loop.



A



B

The retrograde catheterization procedure of the jejunum involves the serial use of standard angiography guidewires, such as the 15 J, Rosen, the stiff Amplatz exchange guidewires (Cook, Inc.), and the Terumo angled guidewire (Mediatech, Watertown, MA); and such catheters as a 6.5-French catheter with a cobra tip and the 7-French Berenstein catheter (Bard, Covington, GA). Successive loops of small bowel generally could be negotiated with ease under fluoroscopic guidance unless they were kinked by intraperitoneal adhesions or the length of the bowel between the jejunostomy site and the stomach remnant was unusually long. In one case, we found it easier to catheterize the small bowel antegradely through the mouth with a long cobra catheter and then retrieve the protruding exchange guidewire through the jejunostomy site with a deflecting wire. It was then possible to advance an 18-French sump drain in a retrograde manner to the lower esophagus.

Although it was possible in two cases to advance a guidewire from the jejunostomy site to the remnant of the stomach, the sump drain could not be inserted because of friction due to kinking of multiple bowel loops. In these patients, a catheter was passed through the nose to the stomach to allow insertion of a large retrieval basket or a nitinol snare (Microvena Corp., Minneapolis, MN). The guidewire tips were then easily snared and pulled back to create enough tension to permit threading of the drain from the jejunostomy site to the esophagogastric junction (Fig. 2). Once secured in position, the retrograde jejuno gastric tubes were quite stable and were not affected by peristalsis. Except for an occasional fever spike, which might be related to the procedure, no morbidity was associated with placement of the small-bowel drain or percutaneous jejunostomy. No pericatheter leakage occurred at the surgical jejunostomy site, even after dilatation to allow insertion of the jejuno gastric tube and the jejunal feeding tube.

Discussion

Diversion of nasopharyngeal secretions from sites of postoperative esophagogastric or jejunal anastomotic leakage is an important step in the management of associated mediastinal or intraabdominal fistulas, outlet strictures, and gastric atony in patients with esophageal or gastric cancer. Percutaneous gastrostomy for continuous aspiration of secretion is not an option in these cases unless the patient has a fairly large gastric remnant not covered by adherent colon. The use of long-term nasogastric aspiration with tubes larger than 12-French can be exceedingly painful for such debilitated patients and often a problem of management for the staff because of the tubes' frequent accidental displacement or removal and sometimes difficult reinsertion.

Inasmuch as all these patients receive enteric feeding, we thought that we could perhaps use the surgically placed jejunostomy for both feeding and insertion of a retrograde

jejuno gastric or esophageal sump tube. This was possible in three patients, and no skin leakage from the jejunostomy site occurred, despite dilatation of the site to accommodate the second drain.

The retrograde jejuno gastric intubation procedure can be time-consuming in some patients who have an unusually long length of jejunum to be catheterized with multiple twists and turns. The technique can be greatly simplified by creating a more proximal fresh percutaneous jejunostomy to bypass encased unnegotiable bowel kinks and to shorten the length of jejunum that must be intubated. We were quite surprised to find that a percutaneous jejunostomy was safe and technically simple to create in these patients and we did not need to insert a nasojejunal balloon catheter to serve as a target for a puncturing needle [4] (Cope C, presented at the Society of Cardiovascular and Interventional Radiology meeting, March 1989). A suitable bowel loop could be selectively opacified via the more distal jejunostomy site and then readily catheterized, because it was fixed in position by tumor or postoperative adhesions; in fact, we had to use an anchoring device [5] in only one patient in order to fix a freely movable jejunal loop to the abdominal wall. As a result, we think that percutaneous jejunostomy should be strongly considered if the surgical jejunostomy site is more than two bowel loops from the distal esophagus or gastric stump.

Retrograde jejunal aspiration was initially accomplished in four of six patients with nasogastric tubes or Salem sump tubes (Sherwood Medical, St. Louis, MO) 12- to 18-French in size. These were sometimes difficult to advance over a guidewire because of frictional resistance. Therefore, we now use 90-cm-long 16-French Ring-McLean sump tubes (Cook, Inc.), which are easier to insert and less given to kinking. The drains were not affected by peristalsis and remained in good position for continuous or intermittent suction or gravity drainage throughout the course of the patient's treatment. The drains were well tolerated and easily managed without complicating infections at the insertion sites.

In conclusion, we describe a novel technique for replacing nasogastric drainage by retrograde esophagogastric drainage. This technique appears to be safe and efficacious, and it increases the patient's comfort and facilitates nursing care.

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Case Report

Arteriovenous Malformation of the Small Bowel Diagnosed with Enteroclysis

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With the increasingly accurate diagnostic workup of gastrointestinal bleeding, a source of bleeding is found in 94–95% of patients who undergo radiologic and/or endoscopic examinations of the upper and lower gastrointestinal tracts [1, 2]. The remaining 5–6% of patients with unexplained bleeding are often found to have lesions in the small bowel. Arteriovenous malformations are thought to be the most common cause of bleeding from the small bowel [1, 3]. In recent years, these lesions have been diagnosed at enteroscopy or at surgery. However, we report a case of a jejunal arteriovenous malformation that was discovered with enteroclysis. To our knowledge, this is the first report of such a lesion demonstrated by this technique.

Case Report

A 60-year-old man was examined by his physician after recent onset of melena. Upper endoscopy was normal, but a ^{99m}Tc-RBC scan was interpreted as showing blood loss into the proximal small bowel. After another episode of gastrointestinal bleeding, the patient was admitted to our institution. Colonoscopy was normal, and angiography did not show a bleeding site or vascular abnormality in the small or large bowel. However, subsequent enteroclysis showed a 4-mm-wide, slightly lobulated filling defect involving a 15-mm-long portion of a single circular fold in a proximal loop of jejunum (Figs. 1A and 1B). This finding was thought to be suggestive of an arteriovenous or venous malformation. Three days later, surgical exploration of the abdomen revealed several dilated vessels on the serosal surface of the proximal jejunum. Intraoperative enteroscopy demon-

strated a small, ovoid, erythematous, raised lesion about 40 cm beyond the ligament of Treitz. A small amount of blood was seen oozing from this region. Transillumination revealed a markedly dilated blood vessel. The lesion was thought to represent an arteriovenous malformation. The area was marked by a suture, and a 15-cm long segment of small bowel was resected. Examination of microscopic sections taken from the area of the specimen marked by the suture showed changes consistent with a vascular malformation. Abundant thin-walled, large-caliber vessels in the submucosa had the appearance of veins rather than arteries. These vessels could be seen extending into the submucosal core of a fold (Fig. 1C). The patient tolerated the procedure well, and gastrointestinal bleeding did not recur postoperatively.

Discussion

Arteriovenous malformations are thought to be the most common cause of bleeding from the small bowel. In two series of patients who recently had undergone enteroscopy for obscure gastrointestinal blood loss, arteriovenous malformations accounted for about 80% of all small-bowel lesions seen at enteroscopy [1, 3]. In those same studies, however, enteroscopy showed a possible bleeding site in the small bowel in only 33–44% of patients [1, 3]. Thus, enteroscopy has limitations in the evaluation of obscure gastrointestinal bleeding.

We have reported an arteriovenous malformation of the small bowel that was recognized at enteroclysis by the presence of a slightly lobulated filling defect oriented along a fold

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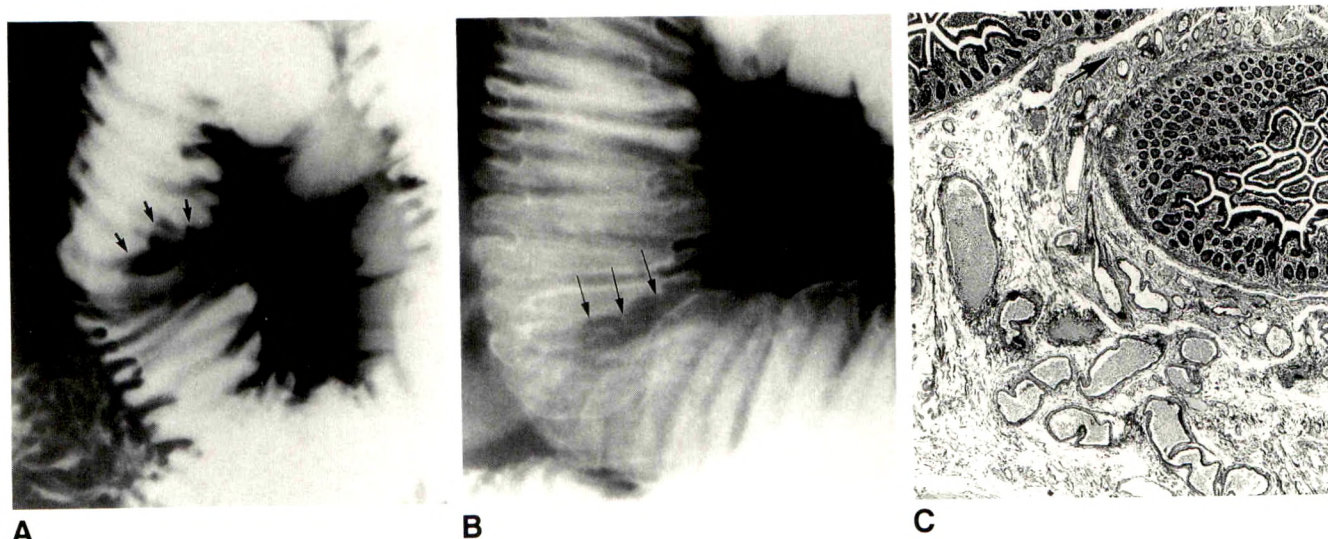


Fig. 1.—Arteriovenous malformation of jejunum.

A, Single-contrast radiograph of proximal jejunum during early phase of enteroclysis shows a 15-mm-long lobulated filling defect (arrows) in bowel.
 B, Additional radiograph of same loop from later double-contrast phase of examination again reveals a lobulated expansion of a 15-mm-long portion of a single fold (arrows) in proximal jejunum.
 C, Low-power photomicrograph of resected specimen shows numerous dilated vessels in submucosa with extension of these vessels into submucosal core (arrow) of a small-bowel fold. Final pathologic diagnosis was arteriovenous malformation.

in the proximal jejunum (Figs. 1A and 1B). Arteriovenous malformations should be differentiated from hemangiomas, which are benign hamartomatous tumors occasionally seen radiographically as polypoid masses in the jejunum or ileum [4]. In any case, our experience suggests that an optimally performed enteroclysis examination is capable of demonstrating relatively subtle lesions in the small bowel, such as arteriovenous malformations. Enteroclysis may be performed prior to enteroscopy or when enteroscopic findings are normal in order to detect lesions that are beyond the range of the endoscope [2].

Arteriovenous malformations represent alterations of normally occurring vessels in the gastrointestinal tract. In the classification system for arteriovenous malformations used by Moore et al. [5], type I lesions are acquired areas of angiodysplasia, found most frequently in the colon of older patients. Type II lesions usually are found in the stomach or jejunum and are congenital lesions, so that they tend to occur in somewhat younger patients. Although type I lesions can be demonstrated with endoscopy or angiography, type II lesions are less reliably shown by angiography because of their predominantly venous composition [6]. When type II lesions are located in the small bowel, however, they can be demonstrated with enteroscopy or, as in our case, with enteroclysis.

In summary, we have reported a case of obscure gastrointestinal blood loss in which the diagnosis of a small-bowel arteriovenous malformation was first suggested by findings with enteroclysis. Radiologists should be aware of the potential role of enteroclysis in the detection of arteriovenous malformations or other small lesions in the small bowel of patients with unexplained gastrointestinal bleeding. Further experience will be necessary to determine how often these lesions can be diagnosed with the use of enteroclysis.

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Case Report

Transcatheter Placement of a Metallic Stent for Treatment of an Occluded H-Graft Portacaval Shunt

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Treatment of patients with portal hypertension and bleeding esophageal varices is one of the most complex problems in clinical medicine. The optimal therapeutic approach must be carefully selected, and detailed examination of the patient is of utmost importance [1, 2].

Treatment options include both noninvasive and invasive (surgical and nonsurgical) procedures [1–3]. The conventional end-to-side portacaval shunt was one of the first operations to be performed in such patients [4]. However, portacaval shunts are associated with a high risk of encephalopathy and hepatic failure caused by decreased portal flow [4]. In 1967, Warren et al. [5] described selective decompression of the portal system to preserve portal flow. In 1980, Rypins and Sarfeh [6] reintroduced the concept of partial portal decompression; they used 10-mm portacaval grafts and ablation of portosystemic collateral vessels. Recently, the diameter of such "H grafts" has been decreased to 8 mm with good early hemodynamic results [2, 7]. However, early thrombosis of these smaller diameter grafts occurred in 15% of patients [7], and postoperative angiography and transcatheter recanalization of thrombosed grafts has become an important adjunctive procedure in these patients. We report a case of chronic occlusion of a small-diameter H-type portacaval shunt successfully treated with transcatheter recanalization and placement of a metallic stent.

Case Report

A 47-year-old man had liver cirrhosis, portal hypertension, and esophageal varices grades III–IV. The patient had a history of recur-

rent upper gastrointestinal tract bleeding that had been treated with sclerotherapy. He also had ascites and portal hypertensive gastropathy. Sclerotherapy was attempted unsuccessfully. A side-to-side portacaval shunt with a Gore-Tex interposition graft (10 mm in diameter, 5 cm long) was constructed.

Five months after surgery, upper gastrointestinal tract bleeding recurred. An angiogram obtained via a femoral vein approach showed severe stenosis in the proximal anastomosis of the portacaval shunt. The shunt was selectively catheterized and dilated with a 6-mm angioplasty balloon, with good results. After the procedure, the pressure gradient through the graft was less than 10 mm Hg.

Eight months later, the patient had another episode of variceal bleeding. Because he was not considered a good candidate for surgery, the patient was referred for angiographic evaluation and possible percutaneous treatment of graft failure.

The Gore-Tex portacaval shunt was occluded (Fig. 1A). Injection of contrast material into the superior mesenteric vein showed occlusion of the portal vein with reconstitution of the intrahepatic portal branches via collaterals. Extensive gastric and esophageal varices were present.

Recanalization of the thrombosed segment of the graft was achieved by using a Sidewinder catheter (Medi-tech Inc., Watertown, MA) and a Terumo guidewire (Terumo Corp., Tokyo, Japan). Subsequently, the stenosed segment was dilated by using 5- and 8-mm angioplasty balloons; however, the results were poor (Fig. 1B). For this reason, it was decided to place a self-expandable metallic stent (Wallstent, Schneider Inc., Minneapolis, MN) 10 mm in diameter and 42 mm long. After the procedure, angiograms showed complete recanalization of the portacaval shunt and excellent flow of contrast material into the inferior vena cava (Fig. 1C). The portosystemic gradient, which was 29 mm Hg before the procedure, decreased to 15 mm Hg after placement of the stent. No significant pressure gradient was found along the inferior vena cava.

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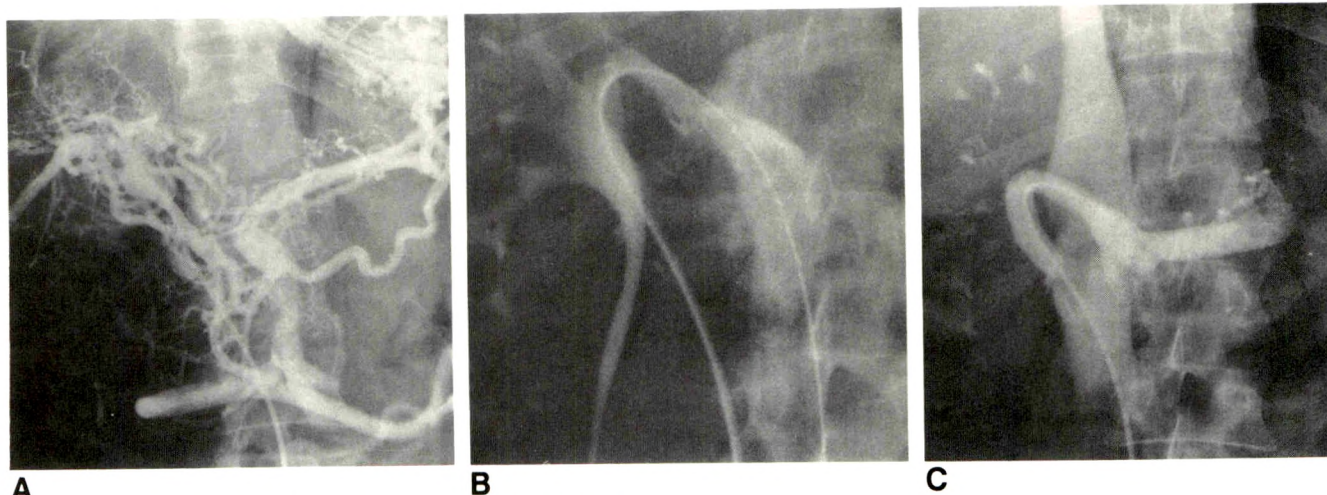


Fig. 1.—Occlusion of a surgical portacaval shunt in a 47-year-old man.
 A, Superior mesenteric phlebogram shows occlusion of portal vein with reconstitution of intrahepatic portal vein branches. Note extensive gastric and esophageal varices. Gore-Tex graft did not opacify.
 B, Superior mesenteric phlebogram obtained after balloon dilatation shows persistent narrowing of graft.
 C, Phlebogram obtained after stent placement shows excellent flow through stent into inferior vena cava.

The patient's clinical condition was excellent after the procedure. At follow-up examination 6 months later, the patient was still asymptomatic.

Discussion

Surgical portosystemic shunting plays a critical role in the treatment of patients with bleeding esophageal varices [8], and several surgical options are available. Different studies have found various degrees of operative mortality and post-operative shunt thrombosis, encephalopathy, and recurrent bleeding [8]. Recently, small-diameter H-graft shunts have been used with increasing frequency [2, 6, 7]. One of the most common early complications with this procedure is graft thrombosis, which occurs in 11–15% of patients [2, 7]. This high prevalence has given the interventional radiologist an opportunity to have an active role in the diagnosis and treatment of this complication [2, 6, 7], because surgical correction of the problem is difficult and these patients are usually poor candidates for surgery [2].

Balloon dilatation of stenotic surgically created portacaval shunts has been performed with various degrees of success. Occluded shunts have been treated percutaneously by using fibrinolytic agents and balloon dilatation. Fibrinolytic therapy, however, must be monitored carefully in these patients because of the increased risk of bleeding from esophageal varices or retroperitoneal hemorrhage. In our case, balloon angioplasty was initially used to recanalize an occluded H graft, and, months later, because of reocclusion, a metallic stent was successfully placed across the H graft. We think that the placement of metallic stents through these surgically created portacaval shunts is an adequate treatment, as results with these metallic stents in other areas of the vascular

system have been good [3, 9, 10]. The Wallstent prosthesis was chosen because of its flexibility and adaptability to tortuous blood vessels, which were an important feature in our case.

The results in our case were extremely good, with establishment of blood flow across the portosystemic shunt and satisfactory portosystemic pressure gradient after stent placement. The long-term patency rate of the Wallstent prosthesis in this specific problem is unknown, and further clinical experience with similar cases will be needed in order to define the role of this technique in clinical practice.

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The Natural History of Renal Lesions in von Hippel-Lindau Disease: A Serial CT Study in 28 Patients

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OBJECTIVE. Von Hippel-Lindau disease is a multisystem disorder predisposing to renal cysts and cancer. The growth and development of these renal lesions have not been documented previously. We reviewed serial CT scans to determine the rates and patterns of growth of renal lesions associated with von Hippel-Lindau disease.

SUBJECTS AND METHODS. Twenty-eight patients with von Hippel-Lindau disease and renal involvement, including the spectrum from simple cysts to solid masses, had follow-up examinations for at least 1 year (mean, 2.4 years; range, 1–12 years) with serial contrast-enhanced abdominal CT. Renal lesions were measured and characterized. Surgical correlation was available in 12 patients.

RESULTS. Two hundred twenty-eight lesions (eight lesions per patient) were detected. On the basis of their CT appearance, 168 lesions (74%) were classified as cysts, 18 (8%) as cysts with solid components, and 42 (18%) as solid masses. Among 12 patients with pathologic confirmation, the solid components of cystic lesions and solid lesions almost always contained renal carcinoma. The majority of cysts remained the same size (71%) or enlarged (20%); 9% became smaller or entirely involuted during the follow-up period. Although it is generally presumed that renal cysts are precursors to cancers, the transformation of a simple cyst to a solid lesion was observed in only two patients. Among the 42 solid lesions, all but two enlarged with time, with a mean doubling time of 10 months.

CONCLUSION. The renal lesions associated with von Hippel-Lindau disease exhibited wide differences in growth. The majority of renal cysts grew slowly but some involuted. Transition to solid renal cancer was rare among cysts. Complex cystic and solid lesions contained neoplastic tissue that uniformly enlarged. These data may be used to help predict the progression of renal lesions in von Hippel-Lindau disease.

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Von Hippel-Lindau disease is caused by a genetic defect in the short arm of chromosome 3 and results in retinal angiomas, CNS hemangioblastomas, pancreatic cysts and tumors, pheochromocytomas, and renal cysts and tumors [1, 2]. Although a spectrum of renal lesions from cysts to tumors are known to occur, there is little information about their biologic activity. Specifically, it has been suggested that cysts might be the precursor lesion to renal carcinoma [3–5]. This is based on the observation that small foci of cancer can be found in the wall of many renal cysts in this disorder. Although this is an attractive theory, this sequence has not been verified in vivo and doubts have been raised about its validity [6].

The advent of abdominal CT scanning makes possible the serial evaluation of renal lesions associated with von Hippel-Lindau disease [7, 8]. CT has been in widespread use for over a decade, and data on the natural history of such lesions are beginning to accumulate. We used these data to demonstrate the natural history of renal lesions in 28 patients.

Subjects and Methods

From 1987 to 1991, 311 persons at risk for von Hippel-Lindau disease or known to have the disease were screened as follows. Unenhanced and contrast-enhanced (Isovue 300, Squibb, Princeton, NJ) CT scans (General Electric 9800, Milwaukee, WI) of the abdomen were obtained. Initial contrast-enhanced CT scans were obtained by using 10-mm-thick contiguous sections and a machine-injected (Medrad, Pittsburgh, PA) bolus of 100–120 ml of contrast material. Follow-up scans were usually obtained by using 5-mm-thick contiguous sections or 10-mm-thick contiguous sections (if obtained outside our institution). Patients less than 18 years old had abdominal sonography rather than CT. However, if the sonograms showed renal lesions, CT scans were obtained.

Every effort was made to obtain previous radiologic images. A variety of CT scanners and techniques were used at outside institutions. The nominal requirement for inclusion in this study was that the CT scans were obtained by using 10-mm-thick contiguous sections and IV contrast material.

Of the 311 persons screened, 81 had von Hippel-Lindau disease. Fifty-one (63%) of these had renal manifestations of the disease. Four of the 51 had metastatic disease and were excluded from consideration for this study. The mean and standard deviation of tumor size in these four patients was 8 ± 2.2 cm (range, 7–12 cm). Two other patients had bilateral nephrectomies and thus could not be followed up. Seventeen patients have not yet been reexamined or their follow-up study is insufficient.

Of the 51 von Hippel-Lindau patients with renal manifestations, 28 (55%) have had follow-up examinations for at least 1 year (mean, 2.4 years; range 1–12 years) and constitute our study population. CT scans of each patient were available for review. The ages of the patients when renal cysts or solid tumors were diagnosed were recorded in each case. Figure 1 shows the cumulative probability of renal cysts and renal tumors developing, based on the ages of the patients when the lesions were diagnosed.

Patients in whom renal lesions were detected during screening tests returned at least 6 months later for further imaging studies and then had follow-up examinations, generally at 6-month to yearly intervals. In several cases, the changes in the disease or the need for a preoperative study justified a shorter interval.

The sizes of the renal lesions detected on CT scans were measured by using hand-held calipers. The dimensions of each lesion were recorded. For volume determinations, the lesion was assumed to be either a sphere (if the dimensions were within 5 mm of each other), for which the volume formula is $(4/3)\pi r^3$, or a prolate ellipsoid (if the dimensions differed by more than 5 mm), for which the volume formula is $d_1 \times d_2 \times d_3 \times 0.523$, where d_i is the diameter in each orthogonal plane [9]. A qualitative description of the density and degree of enhancement of each lesion was recorded.

Lesions were classified as cystic, complex (cystic with solid components), or solid. A lesion was considered cystic if its attenuation on CT scans was similar to that of water (<20 H) and it did not enhance with contrast material. A lesion was considered complex if it was mostly cystic but also contained solid elements that enhanced with contrast material. High-density lesions that did not enhance also were considered complex. A lesion was considered solid if it had an attenuation higher than that of water (>20 H) and enhanced with contrast material. The presence of renal scars and calcifications was also recorded.

In 12 patients, pathologic material was obtained by surgery. Lesions were mapped and numbered from the CT scan that was used to number the pathologic specimens. The presence of renal cancer within a particular lesion was specifically sought and recorded. Pathologic validation was not available in the remaining patients, who continue to be followed up.

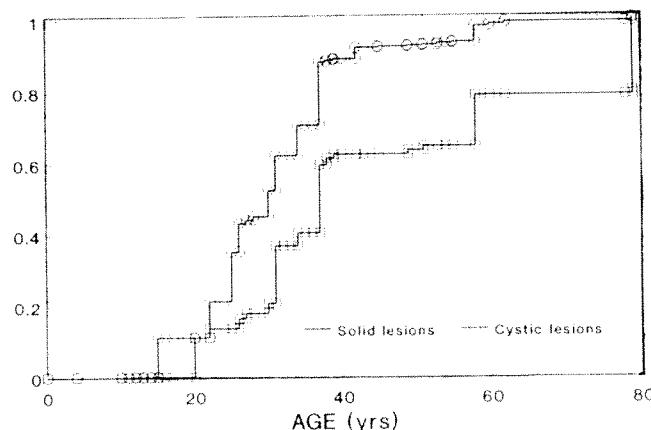


Fig. 1.—Graph shows cumulative probability that a patient in this study would be diagnosed with renal cysts (circles) or solid renal masses (squares) as a function of age. Note no solid renal lesions were seen before age 16. Cystic lesions in general preceded solid lesions by 3–7 years in most cases. The number of new diagnoses of renal lesions after age 60 is small.

Results

The 28 patients who had serial studies had a total of 228 lesions. The lesions were bilateral in 21 cases and unilateral in seven, yielding about five lesions per involved kidney. According to CT criteria, 168 (74%) were cysts, 18 (8%) were cystic with solid components, and 42 (18%) were solid lesions. Thirteen scars and four completely calcified renal lesions were also found. An additional 58 lesions (1–4 mm in diameter) developed during the observation period, but most were too small to characterize accurately. Thus, on average, a new renal abnormality developed in each patient every 1.3 years. Those patients who were followed up the longest (7–11 years) had a gradual increase in the number of lesions with time. Figure 1 demonstrates that cysts precede tumors in the development of renal lesions. Almost all renal lesions in patients with von Hippel-Lindau disease were disclosed by age 60.

Cysts

Most of the renal lesions (74%) were cysts, and these occurred in all patients. A range of growth patterns was seen. The majority, 119 (71%) remained stable during the follow-up period; 33 (20%) enlarged without any change in the density of the cystic fluid or wall thickness to suggest the development of a malignant neoplasm. The average increase in diameter was 0.5 cm/year, with maximal growth rates of 1.6 cm/year. Fifteen (9%) became smaller, including six that completely involuted, leaving only a scar on the renal contour (Fig. 2). Only two lesions in two patients transformed from cystic to solid over a period of 5 years (Fig. 3).

Lesions with Cystic and Solid Elements

Eighteen lesions (8%) in 11 patients had both cystic and solid elements (Fig. 4). In 15 of these, both the cystic and the

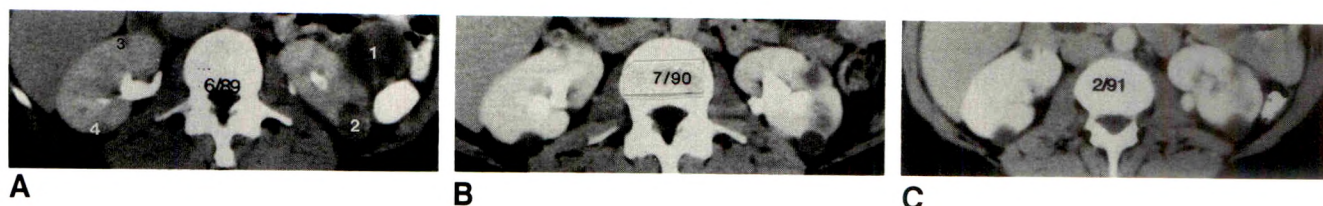


Fig. 2.—A–C, Serial enhanced CT scans obtained at intervals over 20 months show variable behavior of cysts in von Hippel-Lindau disease. Cyst 1 is initially a large cyst that involutes to a scar. Cyst 2 is a complex lesion that becomes smaller but does not completely involute. Lesion 3 is not present initially but develops into a thick-walled complex lesion with an enhancing rim. Cyst 4 enlarges.

Fig. 3.—A–D, Serial enhanced CT scans obtained at intervals over 57 months show unusual conversion of a cyst to a solid renal carcinoma. Cyst 1 remains relatively stable during this period (A). Cyst 2, however, becomes mixed (B) and then turns solid (C) and enlarges (D) (arrows). Pathologic diagnosis: lesion 1, cyst with epithelial hyperplasia; lesion 2, renal cell carcinoma.

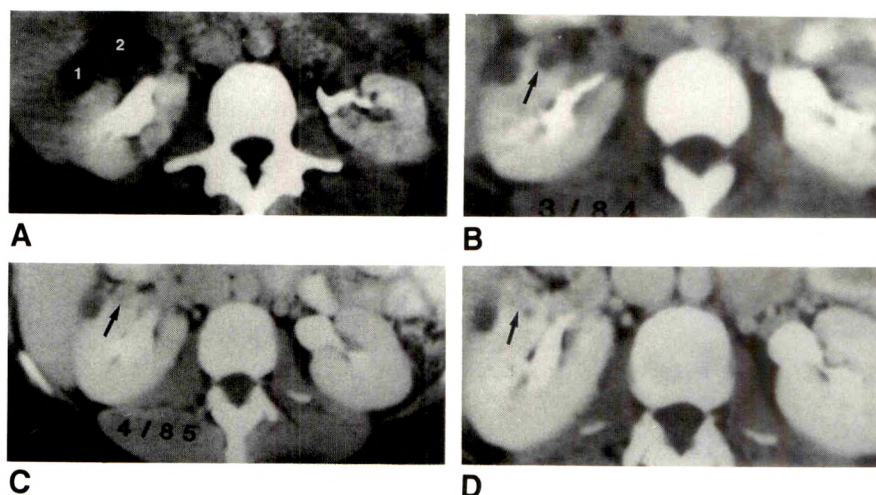
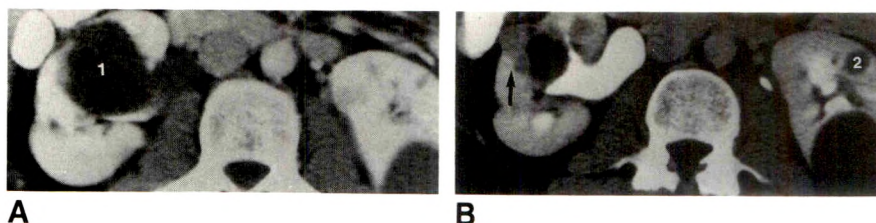


Fig. 4.—A and B, CT scans obtained 8 months apart show rapid involution (B) of cystic component of lesion 1, which contained cystic and solid elements. In same interval, solid component enlarged (arrow). Pathologic diagnosis: cystic renal cell carcinoma, well differentiated. A new solid lesion (2) developed in right kidney. The two sections of left kidney are at slightly different levels.



solid elements showed moderately slow growth during the observation period. In three cases, the complex lesion appeared to transform from a complex cyst to a predominantly solid lesion that continued to grow. Thus, it appeared that the cystic part of the lesion gradually involuted as the solid part enlarged.

Solid Lesions

Forty-two lesions (18%) in 19 patients were solid, and all but two enlarged. The average doubling rate was 10 months; however, the doubling time in one was 1 month (Fig. 5). Diameters increased 0.2–2.2 cm/year (mean, 1.6 cm/year). Eight tumors began as tiny foci within the renal parenchyma and grew to be 2–3 cm in diameter over a period of 2–4 years (Fig. 6). During growth, the CT appearance of the lesion did not change; the attenuation of the lesion remained higher than that of water, and the lesion enhanced uniformly with contrast material. All solid lesions were removed by the time they attained a size of 3 cm. Bilateral solid masses occurred

in 12 (63%) of 19 patients. No metastatic lesions have developed to date in patients who have been followed up. The growth rates of selected solid lesions are shown in Figure 7.

The proportion of solid lesions to the total number of lesions did not increase with age, nor did the rate of development of solid or cystic lesions increase with age. However, we found a weak positive correlation ($r = .66$) between the total number of lesions per patient and the maximal growth rate of the fastest growing solid lesion. Thus, patients with more lesions tended to have faster growing renal tumors (Fig. 8).

Miscellaneous Lesions

In addition to the lesions already described, four completely calcified masses 3–10 mm in diameter were found. Another finding in eight patients consisted of a small scar in the contour of the kidney. In many cases, no other lesions were found. In six cases, the scar appeared at the site of a previous, but now involuted, cyst (Fig. 2).

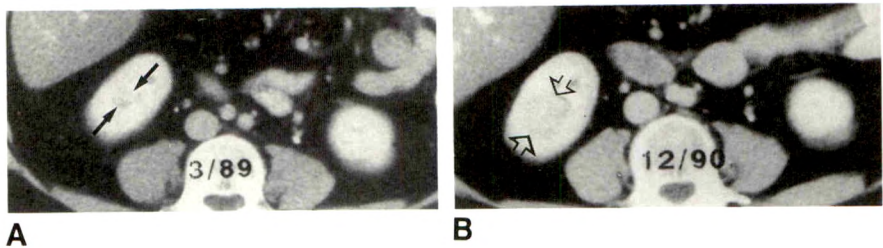


Fig. 5.—A and B, CT scans obtained 21 months apart show rapid growth of solid renal carcinoma in von Hippel-Lindau disease. Carcinoma in A (solid arrows) grew to be a 2.5-cm mass (B, open arrows). Pathologic diagnosis: solid renal cell carcinoma.

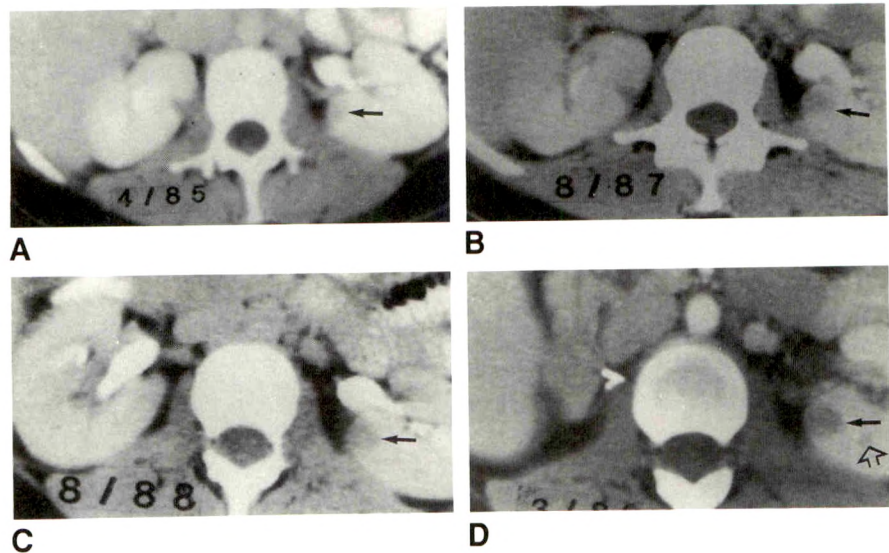


Fig. 6.—A-D, Serial CT scans obtained at intervals over 47 months show progressive enlargement of solid renal mass (solid arrows). A second lesion (open arrow, D) developed. Right kidney was removed because of a large mass. Pathologic diagnosis: solid renal cell carcinoma.

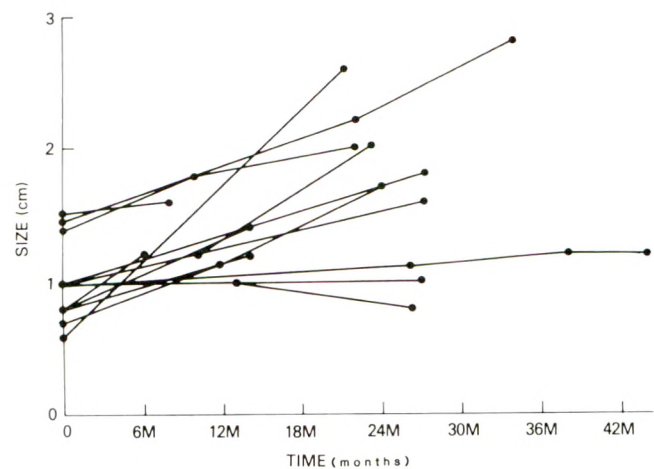


Fig. 7.—Graph shows selected solid renal masses, indicating that solid lesions almost uniformly grew.

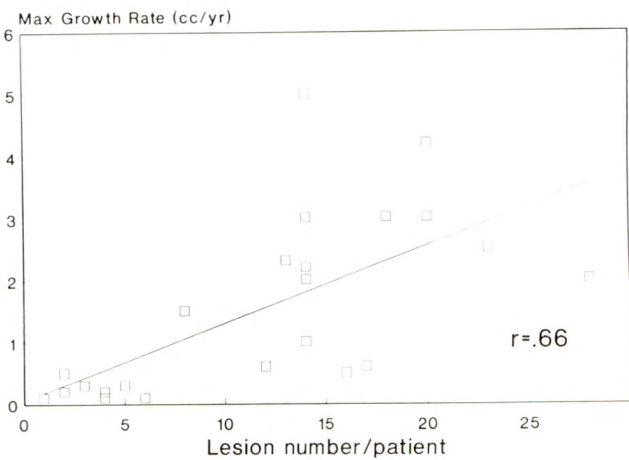


Fig. 8.—Scatter diagram shows relationship between total number of renal lesions per patient vs growth rate in cubic centimeters per year of the fastest growing solid tumor in that patient. Line represents linear regression of these data. These two parameters have a positive linear correlation ($r = .66$).

Discussion

Von Hippel-Lindau disease is associated with a genetic defect at a locus on the short arm of chromosome 3 and is inherited in an autosomal dominant pattern [1]. Among the most common manifestations are retinal angiomas, CNS hemangioblastomas, pancreatic cysts and tumors, pheochromocytomas, and renal cysts and tumors [1, 2]. Clinical heterogeneity is manifested as clustering of abnormalities or phe-

notypes among different families with the disease [10, 11]. Also, the age of onset and severity of the illness among different patients from the same kindred may be quite variable. The variability of the disease between and within affected families, despite tightly linked genetic markers to the 3p25-26 locus, suggests several possible genetic bases for von Hippel-Lindau disease. These include mutant alleles of a

single gene, clustering of several mutant genes at this locus [3, 10–14], and multistep mutations with random accumulation of hits in clonogenic target cells.

Renal involvement occurs in 28–66% of patients with von Hippel-Lindau disease, and bilateral renal cell carcinomas develop in 63–75% of those with renal lesions [7, 15–19]. Metastatic renal carcinoma is the cause of death in 18–33% of von Hippel-Lindau patients [4, 11, 15, 18]. Published reports include patients from all family types that had the diagnosis of von Hippel-Lindau disease, and thus the rates may be higher or lower within individual families. The renal lesions associated with von Hippel-Lindau disease vary from simple cysts with one or two layers of epithelium to hyperplastic cysts with multiple cell layers and cysts containing clear cell carcinomas [4, 5, 20]. Completely solid renal cancers and hyalinized fibrotic nodules (presumably involuted cancers) have also been described [4]. The lesions are usually bilateral and mostly cystic; however, the full pathologic spectrum can be seen within a single kidney. This has led to the suggestion that renal cancers in von Hippel-Lindau disease result from a single genetic defect in a tumor suppressor gene, producing renal cysts that eventually progress to cystic or solid tumors [3–5].

The majority of renal cysts in our study were indolent, with little or no growth over a period of years. Some cysts even involuted, leaving only small scars. We observed the transformation of a cyst to a cancer in only two instances. However, we think that more transformations would have occurred if the observation period had been longer. Despite their benign cystic appearance on CT, small neoplastic elements were frequently found in the wall of these cysts when the cysts were removed. Quantitative DNA studies have shown that both the renal cell carcinomas and the cells lining atypical cysts in von Hippel-Lindau disease have similar amounts and types of DNA [21]. Nevertheless, the majority of the solid lesions in this study appeared to arise *de novo*, and were not initially cystic. Although conversion from cystic to solid lesions does occur, this does not appear to be the predominant sequence of events in the development of renal cancer in von Hippel-Lindau disease. Figure 9 shows the variable growth patterns of renal lesions in von Hippel-Lindau disease. Once solid renal lesions developed, they grew at rates similar to those described for sporadic renal cell carcinomas [22].

The number of lesions in the affected patients gradually increased; the lesions did not appear to have formed all at once and progressed from that point. The weak positive correlation (Fig. 8) between the number of renal lesions per kidney and the maximal growth rate of solid lesions implies that the mechanism that initiates renal lesions may also influence the growth rate of solid lesions.

The high overall prevalence (63%) of renal involvement in our population of patients with von Hippel-Lindau disease probably reflects the thoroughness of the CT examination performed during the screening study. As observed by others [4], the most frequent lesions associated with renal disease are pancreatic cysts, CNS hemangioblastomas, and retinal angiomas. The prevalence of renal involvement may be even higher than this number would indicate, because 22 of the 81

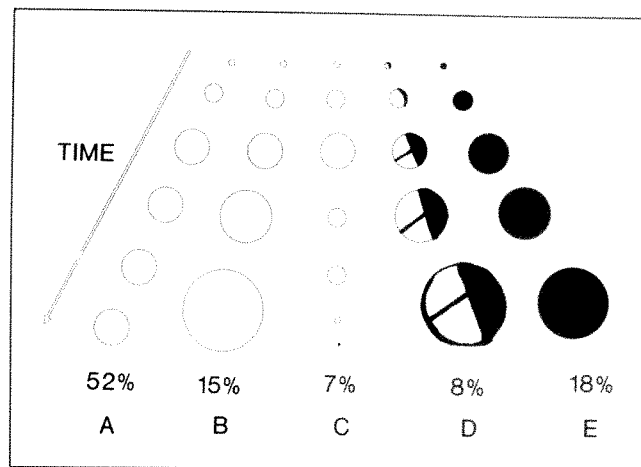


Fig. 9.—Schematic summary of lesion behavior in von Hippel-Lindau disease. Genetic defect resulting in von Hippel-Lindau disease, most likely a deletion in a tumor-suppressor gene, predisposes patient to a spectrum of renal abnormalities: A = slow-growing or stable renal cyst (52%). B = more rapidly growing renal cyst (15%). C = involuting renal cyst that forms a scar (7%). D = cystic-solid renal lesion that enlarges its solid component; cystic component shows variable behavior (8%). E = solid lesions that uniformly grow (18%). Rare event of a cyst transforming to a solid lesion is not illustrated here.

patients with von Hippel-Lindau disease were from a family whose members had retinal angiomas, pheochromocytomas, and CNS hemangioblastomas but no renal lesions [3]. Among the remaining 59 patients, 50 (85%) had renal manifestations.

The variation in the number of lesions and severity of renal disease in von Hippel-Lindau disease fits with the prevailing models of this disease. These models suggest that the manifestations of von Hippel-Lindau disease are due either to the pleiotropic expression of a single gene [13] or to a set of contiguous genes [11]. The severity of these manifestations, however, may also be determined by such factors as the degree of damage to the homologous normal allele [23] or to local factors, such as cell of origin [24]. In the case of renal lesions, Kragel et al. [24] have shown that renal cancers in von Hippel-Lindau disease have proximal tubular epithelial markers, renal cysts have distal tubular epithelial markers, and atypical renal cysts (i.e., those containing neoplastic elements) show a tubular origin similar to that of renal carcinoma. The work of Kragel et al. suggests the possibility that the cell of origin may in part determine the type of lesion that develops.

We currently perform yearly examinations of von Hippel-Lindau patients who have renal lesions and recommend surgery when the size of a renal tumor reaches approximately 3 cm. Although no metastases developed in any of our patients, there is a small risk of metastases developing even with tumors of this size [25, 26]. Nevertheless, preserving renal function for as long as possible should be considered a goal of treatment, and we think CT is helpful in maximizing the interval between surgeries. The four von Hippel-Lindau patients who were not included in this study because they had metastatic disease all had large tumors (mean diameter, 8 cm), consistent with the findings in sporadic renal cell carci-

noma [27]. Spiral CT may play a role in the future in better characterizing small lesions.

The optimal surgical management of renal lesions in patients with von Hippel-Lindau disease is evolving. It could be argued that patients with von Hippel-Lindau disease who have multiple fast-growing tumors of the kidney should undergo bilateral nephrectomy followed by renal transplantation. This approach may be applicable to the most aggressive forms of this disease. In the majority of our patients, however, the disease progressed at a much slower rate, suggesting a role for nephron-sparing surgery [28, 29]. Eventually, some of these patients may undergo bilateral nephrectomy, with subsequent dialysis or transplantation. The treatment of other lesions such as spinal or cerebellar hemangioblastomas or pheochromocytomas is greatly aided by retaining the kidneys for as long as is feasible, consistent with the goal of preventing metastases. Thus, the approach to each patient must be individualized, with special attention to the tempo of disease as judged by progression on serial evaluations. In our series, 60% of patients had at least one renal surgery by age 60. It should be axiomatic that no patient with von Hippel-Lindau disease undergo surgery without thorough screening for pheochromocytoma and CNS hemangioblastoma [30].

In summary, we found that biologically cystic von Hippel-Lindau lesions behave differently than solid von Hippel-Lindau lesions do. Although a minority of cystic lesions converted to solid lesions, the time course of such changes may be longer than our mean observation period. In general, the more numerous the lesions, the more likely that solid lesions are present and that one of the lesions will grow at a faster rate. Serial CT scans are an appropriate way of assessing disease progression and judging the interval between interventions.

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Case Report

Cystic Renal Cell Carcinoma: CT Findings Simulating a Benign Hyperdense Cyst

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Renal masses with attenuation values ranging from 40 H to 90 H on unenhanced CT scans are considered hyperdense lesions. The differential diagnosis for such hyperdense masses includes benign entities such as a hyperdense cyst and primary and secondary malignant neoplasms [1-3]. CT criteria have been proposed to distinguish benign hyperdense cysts from the other hyperdense lesions [1, 4]. We report a case of cystic renal cell carcinoma that fulfilled all of the CT criteria for a benign hyperdense cyst.

Case Report

A 70-year-old man with newly diagnosed stage B prostatic carcinoma had abdominal CT as part of his evaluation. Results of routine laboratory studies, including urinalysis, were all within normal limits.

Contrast-enhanced CT scans showed a 2.5-cm mass in the lower pole of the left kidney. Dedicated renal CT (Figs. 1A and 1B) was performed next and included 3-mm scans through the mass with and without contrast enhancement. The mass was smooth, round, sharply margined, homogeneous, and measured 44.5 H and 43.9 H on unenhanced and contrast-enhanced scans, respectively (Figs. 1A and 1B). The mass remained homogeneous at narrow window settings. Approximately 75% of the circumference projected beyond the renal contour, and the wall of the mass was imperceptible.

A subsequent sonographic examination showed that the mass was cystic (bright back-wall enhancement) but had a few low-level echoes within it. During surgical exploration, the surface of the cystic mass was found to be more vascular than it would be in a typical simple cyst, suggestive of malignancy, and therefore a nephrectomy was performed.

On gross examination, the cystic mass was found to be filled with straw-colored fluid. The wall was smooth without nodularity or focal thickening. On microscopic examination, the cystic mass was seen to be surrounded by a uniformly thickened fibrous wall that was partially lined by a single layer of cuboidal cells with uniform small nuclei and scanty clear cytoplasm (Fig. 1C). Microscopic papillary excrescences composed of branching fibrovascular fronds lined by a single layer of neoplastic clear cells were found in several foci (Fig. 1D). Solid aggregates, nests, or tubular arrangements of tumor were not present, nor was any evidence of parenchymal or vascular invasion found. Degenerative features such as hemorrhage, hemosiderin deposition, or foamy histiocytes were not present. The renal capsule was intact and no vascular invasion had occurred. The final pathologic diagnosis was stage I unilocular cystic renal cell carcinoma.

Discussion

The true prevalence of hyperdense lesions of the kidney is unknown. Hyperdense cysts are a well-known occurrence in autosomal dominant polycystic kidney disease. In one series

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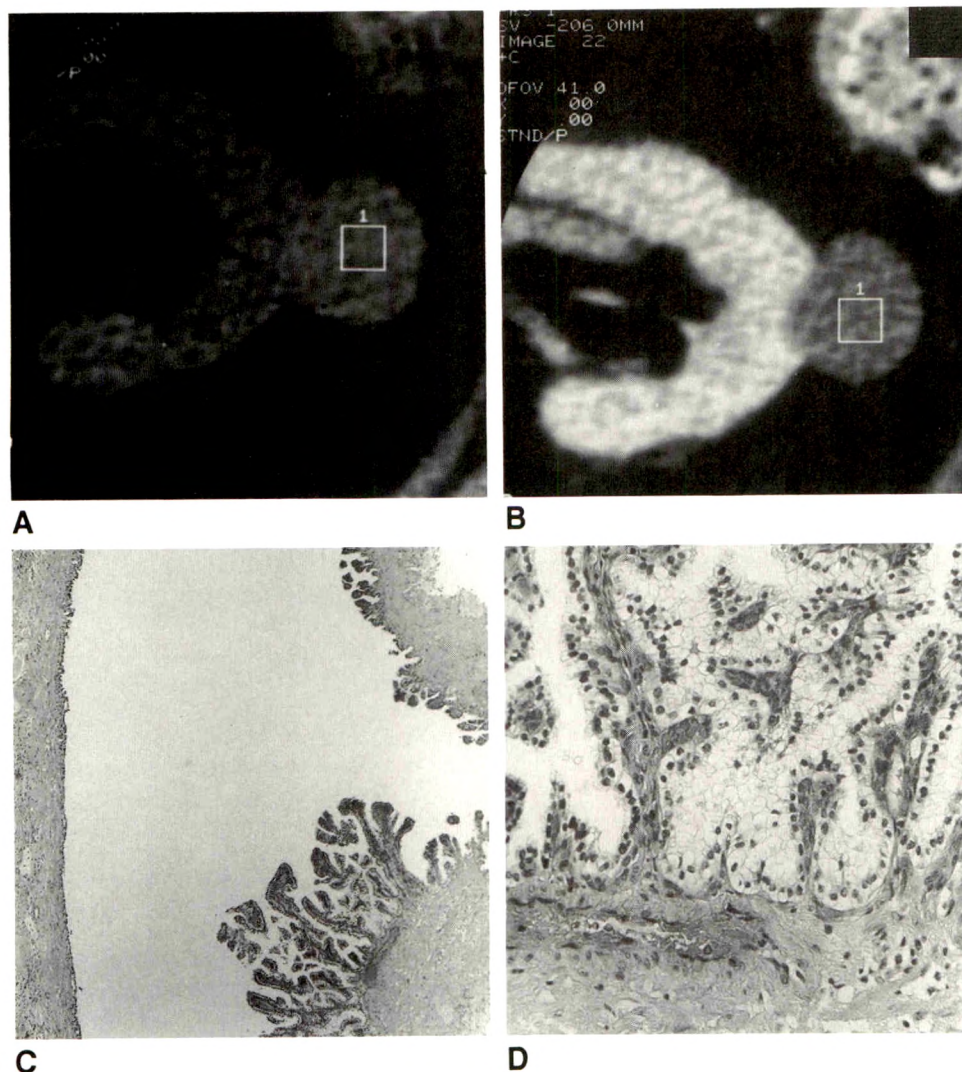


Fig. 1.—A, Unenhanced CT scan of left kidney shows a 2.5-cm, round, smooth, homogeneous mass with attenuation of 44.5 H. Approximately 75% of circumference of mass extends beyond contour of kidney.

B, On enhanced CT scan, mass remains homogeneous and has an attenuation of 43.9 H.

C, Photomicrograph shows that near junction of cystic mass and kidney, tumor is lined by a single layer of neoplastic cells. Laterally, papillary excrescences of tumor project into lumen of cyst. (H and E, original magnification $\times 85$)

D, Photomicrograph shows that papillary fronds are lined by a single layer of neoplastic clear cells exhibiting low-nuclear-grade atypia. (H and E, original magnification $\times 350$)

of patients with autosomal dominant polycystic kidney disease, almost 70% had one or more high-density cysts (58–84 H) [5]. Most other pathologically proved cases of hyperdense cysts have been reported as isolated cases or as part of a small series [2]. Another factor obscuring the true prevalence of hyperdense cysts is that they may be isodense on contrast-enhanced scans. If the enhanced scan is not preceded with an unenhanced scan, the diagnosis may be missed.

Several mechanisms exist by which renal cysts may become hyperdense. Proposed mechanisms by which cysts have elevated CT attenuation include hemorrhage with clot retraction, concentration of the protein components of blood, elevation of iron content, colloid formation, infection, and transient iodine accumulation within a simple cyst [6]. The cause of the hyperdense appearance in this case is unknown.

The following CT criteria have been proposed for a benign hyperdense cyst: (1) The lesion must be perfectly smooth, round, sharply margined, and homogeneous, with CT attenuation values ranging from approximately 40 H to 90 H on unenhanced scans; the lesion must be evaluated with narrow

window settings to be certain it is homogeneous in attenuation. (2) The lesion must not enhance when contrast material is administered IV, and its configuration must remain unchanged. (3) The lesion must be 3 cm or smaller. (4) The lesion must extend outside of the kidney (at least one fourth of its circumference) so that the smoothness of some of the wall can be evaluated [1, 7]. If any of these criteria are not met, further evaluation (e.g., follow-up, cyst puncture, exploration) is required.

When deciding whether a hyperdense cyst is benign or malignant, impeccable technique is required. Partial-volume averaging can become problematic unless the section thickness is less than one half the diameter of the lesion. It is important to regularly calibrate CT attenuation values by using fluid in the gallbladder or unopacified urine in the bladder as an internal standard for water.

CT is more reliable than sonography in differentiating benign and malignant hyperdense cystic lesions. Only 50% of hyperdense cysts meet the sonographic criteria for a simple cyst [7]. They often have less through-transmission than a similar-sized simple cyst or will have a few scattered internal echoes.

The false-negative CT findings in this case can be explained by the unremarkable gross appearance of the mass. The lack of nodularity and uneven wall thickness seen in most cancers was not present on gross inspection in this case. The single partial layer of tumor cells lining the cystic carcinoma is beyond the spatial resolution of CT. Cystic renal cell carcinomas, especially those that are papillary, are usually hypovascular or avascular; this may explain the lack of contrast enhancement in this case.

On the basis of this case and review of previously published cases, the majority of lesions fulfilling the above-mentioned criteria are indeed benign [8]. This case shows, however, that the CT findings in benign and malignant hyperdense cystic lesions overlap. Further careful radiologic-pathologic correlative studies are required to fully elucidate the magnitude of this overlap.

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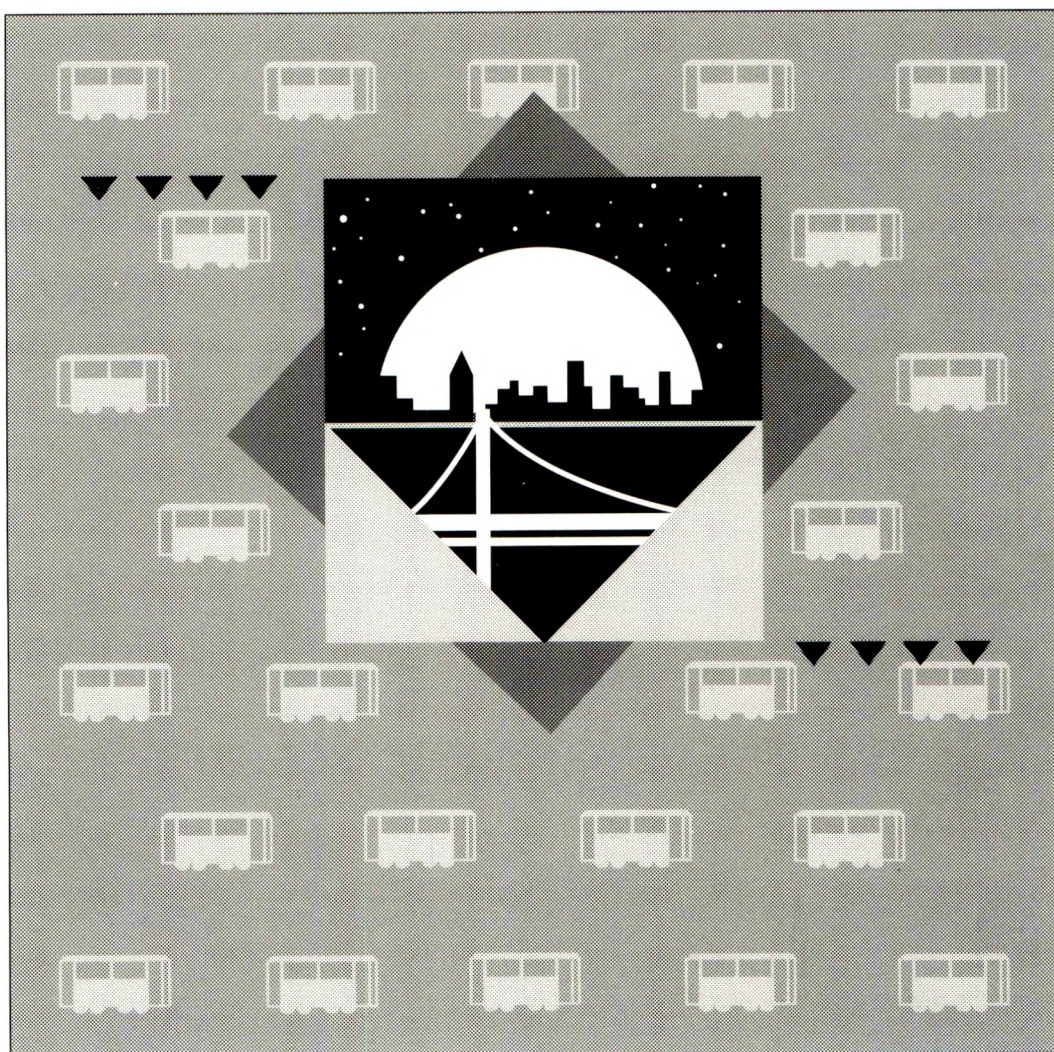
AJR to Use Diskettes Instead of Hard-Copy Manuscripts for Editing and Printing

Beginning with the January 1993 issue, accepted papers to be published in the *AJR* will be edited and printed by using computer diskettes rather than hard copies of the manuscripts. This change will expedite the editing and publication process and result in less delay between submission of manuscripts and their appearance in the Journal. Also, with the new system, authors will receive page proofs rather than galleys before publication. This will enable them to see exactly what their final article will look like.

Effective immediately, upon acceptance of manuscripts for publication, authors will be asked to send a copy of their revised manuscript on a 3½-in. or 5¼-in. DOS-compatible diskette in Wordperfect or ASCII format along with the hard copy of the revision. Articles will be edited directly on the diskettes. Changes will be highlighted electronically; as before, a hard copy of the edited manuscript and figure proofs will be mailed to authors for approval before publication. Note that hard copies of manuscripts will still be required for the peer-review and revision processes.

The *AJR* already takes great pride in the speed with which the peer-review process is accomplished (mean time, 3.4 weeks) and in the amount of time between submission of manuscripts and their final appearance in print (6 months). This is nearly twice as fast as many other journals. With the new system, these intervals will be even shorter. Authors will see their work in print faster, and the timeliness of the Journal will be greater than ever.

Robert N. Berk
Editor-in-Chief



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American Roentgen Ray Society
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Sonographic Findings After Surgical Ablation of the Endometrium

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 Edward G. Grant¹

OBJECTIVE. Endometrial ablation is a new surgical technique that is an alternative to hysterectomy in women with dysfunctional uterine bleeding. The endometrium is either coagulated or resected in an attempt to render the patient amenorrheic. Because of the newness of the procedure, no report of radiologic findings after endometrial ablation has been published. Accordingly, the sonographic appearance of the uterus after endometrial ablation is described.

MATERIALS AND METHODS. Using transvaginal sonography, we examined a select group of 16 women, seven of whom were symptomatic after endometrial ablation. All patients had a preoperative diagnosis of menorrhagia not responsive to conventional hormonal therapy and no evidence of cancer.

RESULTS. In the seven symptomatic patients, sonography showed that postoperatively two had hematometra, one had a nonviable intrauterine pregnancy, and four had residual islands of functioning endometrial tissue alone or in combination with hematometra. In nine asymptomatic patients, postoperative sonography showed seven had normal findings except for leiomyomata and two had residual islands of functioning endometrial tissue.

CONCLUSION. Sonographic examination of the uterus after endometrial ablation provides a method for evaluating symptomatic patients and for identifying any remaining endometrium that could later become symptomatic.

AJR 159:1239-1241, December 1992

Endometrial ablation is a relatively new surgical technique performed as an alternative to hysterectomy. The goal of endometrial ablation is to destroy the endometrium of the uterus in women free of cancer who have intractable, incapacitating bleeding not responsive to conservative measures [1]. In patients who do not have medical contraindications, more conservative, nonsurgical hormonal regimens are attempted first [2].

We discuss the role of transvaginal sonography and describe the sonographic appearance of the uterus in women after endometrial ablation. We know of no other published report of radiologic findings after endometrial ablation.

Materials and Methods

Between August 1989 and April 1992, 372 women underwent endometrial ablation. Of these, seven had transvaginal sonography for specific problems of pain, vaginal bleeding, or both. Nine other patients had routine follow-up sonography. The time between endometrial ablation and transvaginal sonography ranged from 14 days to 24 months. Two patients underwent transvaginal sonography before and after endometrial ablation.

All patients had a preoperative diagnosis of menorrhagia not responsive to conventional hormonal therapy [2]. The patients were from 35 to 69 years old. When the endometrium was sampled before ablation, no malignant tumors were found. Endometrial ablation was done with a continuous-flow 25-French resectoscope (Circon/ACMI, Stamford, CT) equipped with a 2.2-mm roller-ball electrode and a 90°-angle 8 × 5 mm wire loop electrode [2]. The

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Fig. 1.—Normal postsurgical uterus in a 69-year-old woman who had postmenopausal bleeding. Transvaginal sonogram was obtained 14 days after endometrial ablation. Arrows mark endometrial cavity.

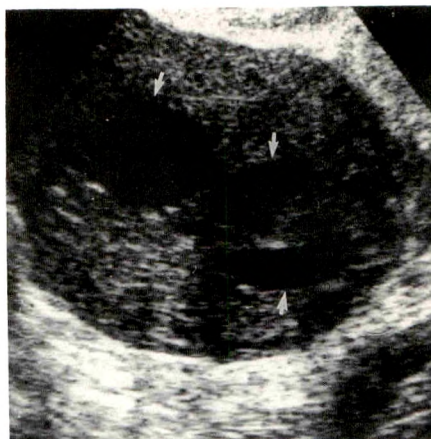


Fig. 2.—Hematometra in a 44-year-old woman who had pelvic pain 4 months after endometrial ablation. Transvaginal sonogram of uterus shows loculated pockets of blood (arrows) distending endometrial cavity.

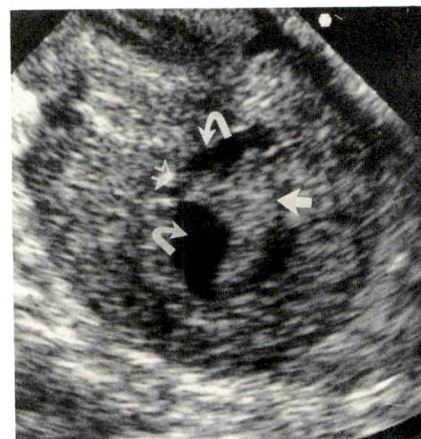


Fig. 3.—48-year-old woman who had pain and bleeding 7 months after endometrial ablation. Transvaginal sonogram of uterus shows residual endometrial tissue within fundus of uterus (straight solid arrow) and loculated collections of blood (curved arrows) separated by synechia (open arrow).

endometrium and a portion of the myometrium were initially resected with the cutting loop electrode, and any remaining tissue was then coagulated with the roller-ball electrode. All patients were scanned with a dedicated 5.0-MHz transvaginal transducer (Advanced Technology Laboratories, Bothell, WA) and standard technique.

Results

Of the 372 patients who underwent endometrial ablation, three required follow-up transvaginal sonography for pelvic pain and four required it for vaginal bleeding. Nine patients had routine follow-up sonography. In the three patients who had pelvic pain, transvaginal sonography showed hematometra in two and a nonviable intrauterine pregnancy in one. The four patients who had vaginal bleeding were found to have residual islands of endometrial tissue alone or in combination with hematometra. The central endometrial echo complex in these four patients ranged from 10 to 15 mm. Seven of the nine patients who had routine follow-up sonograms had normal findings except for leiomyomata. The remaining two patients had residual islands of endometrial tissue measuring 6 mm in one patient and 15 mm in the second patient.

Discussion

Endometrial ablation as a means for controlling dysfunctional uterine bleeding is based on the observation by Asherman [3] that amenorrhea often occurs after a traumatic curettage of the endometrium. The costs associated with hysterectomy led some to investigate surgical and nonsurgical techniques for achieving an Asherman-like syndrome [4–8]. The nonsurgical techniques included the instillation of paraformaldehyde or silicone rubber into the uterine cavity. Not surprisingly, these toxic techniques were abandoned [1]. Currently, the most common surgical technique for ablation

uses a resectoscope equipped with roller-ball and cutting wire loop electrodes coupled to an energy generator that provides a coagulating current [2, 6, 7, 9]. During ablation, the basal layer of the endometrium and a few millimeters of the myometrium are removed [10] (Fig. 1).

Hematometra can have an unusual sonographic appearance because the endometrial cavity becomes scarred after endometrial ablation. Loculated pockets of blood form (Fig. 2), distending the uterine cavity and causing pain [7, 9]. Hematometra may be due to residual blood after the ablation or to islands of functioning endometrium that provide a continued source of bleeding (Fig. 3). Pain after endometrial ablation may indicate the presence of hematometra that has not yet expressed itself by vaginal bleeding. Sonographic examination of the uterus after ablation provides a method for identifying those women in whom the procedure may be unsuccessful by showing any remaining endometrium that could later become symptomatic. Because residual fluid or blood or both may remain in the endometrial cavity immediately after surgery and for a short time thereafter (Fig. 4), McLucas [7], in the absence of complications, recommends a baseline sonogram 3 months after endometrial ablation.

Several authors have discussed the potential risk of masking endometrial carcinoma in the dense synechia that form after endometrial ablation [1, 7, 9]. Small, skipped areas of functioning endometrium can persist after endometrial ablation and later serve as a focus for malignant neoplasms (Fig. 5). With the endometrial cavity occluded by scarring, the early signs of cancer such as bleeding may not be present. This is particularly worrisome because loculated fluid collections that do not manifest as vaginal bleeding tend to form. No long-term studies are yet available on menopausal patients who have undergone ablation [1]. Although endometrial carcinoma is not more common in patients with Asherman's syndrome [11] and is rare with an endometrial thickness less than 8 mm [12], routine follow-up to assess the risk for a hidden malignancy

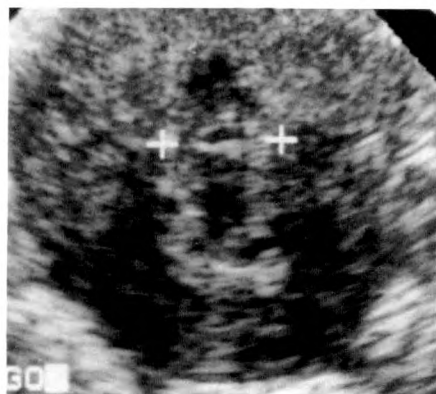


Fig. 4.—Transvaginal sonogram of a 35-year-old woman 3 weeks after endometrial ablation shows residual fluid/blood distending endometrial cavity (between calipers).



A



B

Fig. 5.—Skipped areas of endometrium in a 41-year-old woman who had vaginal bleeding 6 months after endometrial ablation.

A, Transvaginal sonogram of uterus shows residual endometrial tissue (between calipers) measuring approximately 10 mm within fundus of uterus. Normal postsurgical endometrial cavity (arrows) is visible within body of uterus.

B, Transvaginal sonogram after endometrial ablation was repeated 4 weeks later shows a small amount of postsurgical fluid/blood (between calipers).

nant tumor is necessary. Sonography is recommended for women in the age group at highest risk [7]. A baseline sonogram is recommended 3 months after endometrial ablation and then annually [7]. Transvaginal sonography may be an ideal screening test to detect any functioning islands of endometrium that remain postoperatively and then to monitor them on a yearly basis for early changes.

Residual islands of functioning endometrium pose yet another risk, the risk of pregnancy. Additionally, patent fallopian tubes pose a risk of ectopic pregnancy. We observed one nonviable intrauterine pregnancy after endometrial ablation that was easily detected with transvaginal sonography. Although the risk of pregnancy is said to be minimal after endometrial ablation, the true risk of pregnancy after endometrial ablation is unknown because of the newness of the procedure [9] (Hill DH et al., presented at the Third International Congress of Gynecological Endoscopy meeting, November 1990). Therefore, concomitant sterilization such as by tubal ligation has been suggested [7, 9].

We have described several complications occurring after endometrial ablation in a select group of patients, some of whom were symptomatic after endometrial ablation. Although we have begun a long-term follow-up study, no statistics are yet available on all patients after endometrial ablation, symptomatic or not. It has generally been our experience that true complications are rare; however, because of the newness of the procedure, the true prevalence of complications is not yet known. It has been suggested, however, that if only 90% of ablations were successful, 90,000 hysterectomies would be

avoided each year, 2 days of hospital stay avoided, and a savings in operating room and anesthesia time amounting to \$180 million per year would accrue (Brooks PG, presented at the American Association of Gynecologic Laparoscopists meeting, March 1992).

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Early Radiology at the University of Texas Medical Branch, Galveston

Melvyn H. Schreiber¹

In January 1896, a Cleveland *Plain Dealer* article reported Roentgen's success in producing rays that would penetrate wood, flesh, and other organic substances [1]. Dr. Dayton C. Miller, physics professor at Case School of Applied Sciences (later Case Western Reserve), is said to have generated X-rays by early afternoon of the day the article appeared. Arthur Wright of the Yale Physics Department, using a homemade apparatus on January 27, 1896, obtained a clear representation of objects such as a pencil, a pair of scissors, and a coin with X-rays [2]. John Trowbridge, director of Harvard's Jefferson Physical Laboratory, accomplished the same feat and reported his success in the *New York Journal* on February 2, 1896. Edwin Brant Frost, professor of astronomy at Dartmouth, used X-rays to display a Colles' fracture on February 3, 1896, thereby exposing the first clinical radiograph in America [2].

It is uncertain when the first news of Roentgen's discovery reached Galveston. The *Galveston News* of February 23, 1896, presented an extensive report on the discovery and described in considerable detail most of what was known about X-rays at that time.

Dr. Seth Mabry Morris (1867–1952) was the first professor of chemistry in the new Medical School in Galveston. He authored an article entitled "The X-rays" in the March 1896 issue of *University Medical* [3], making clear that he was familiar with the apparatus needed for the production of X-rays and that he anticipated their usefulness in medicine. In the last paragraph of his paper he stated that he had attempted to make radiographs without success, probably due to lack of a coil of sufficient strength.

In 1896, Felix Miller, a first-year medical student and later a surgeon, from El Paso, TX, under the direction of Dr. Morris, began fabrication of an induction coil of sufficient capacity to excite a Crookes' tube to produce useful X-rays. The tube was ordered from Philadelphia, and an invoice for a similar tube showed the price of \$15.

Miller converted a Singer sewing machine into a suitable apparatus for winding the coil with thousands of feet of fine copper wire. He worked in the basement of the old red building (now called the Ashbel Smith Building), the original medical school building, illustrated on the cover of the September 11, 1991, issue of *JAMA*. Near the end of the summer of 1896 Miller completed his task, and Dr. Morris was ready to attempt again to produce satisfactory roentgenograms. That was accomplished during the first or second week of September

1896, the event corroborated by a lengthy article appearing in the *Galveston News* on September 12 of that year. The article described the activities of Dr. Morris in producing roentgenograms of the hands of two young ladies and of a series of metallic objects. Dr. R. D. Cline, professor of pharmacology, assisted Dr. Morris.

The original apparatus consisted of a Rumkoff coil with a Tesla-type interrupter on one end and a spark gap on top. The power may have been provided by a battery or some other source of direct current. It was necessary to interrupt the current at least 10 times per second in order to produce sufficient voltage in the coil. A spark obtained across the spark gap set at 2½ inches would indicate that a voltage sufficient to produce useful X-rays was available.

Exposures for extremities lasted from 10 to 20 minutes. The images were obtained on glass plates covered by emulsion on only one side. Development required solutions kept at a constant temperature of around 75°F, something of a problem during the warm season in Galveston.

The first recorded examination of a patient with this apparatus was early in 1897. The subject was a young man with a bullet lodged in his thigh from a gunshot wound sustained 4 years earlier. An extensive search for the bullet previously was unsuccessful. The roentgenogram clearly located the bullet about 5 inches above the knee, and it was easily removed by Dr. James E. Thompson, professor of surgery [4].

In 1936, the opening address to the incoming freshman class of the medical school was given by Dr. Morris [5]. In it he recounted his experiences as Galveston's first roentgenologist. Much of what we remember about these early days was recorded by Robert N. Cooley, M.D., in his *History of the Department of Radiology, The University of Texas Medical Branch*, published locally in 1986.

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In preparation for the 1995 centennial celebration of the discovery of the X-ray, the *AJR* will periodically publish History Pages, which deal with events leading up to and occurring around the time of the discovery.

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MR Imaging of Pelvic Masses in Women: Contrast-Enhanced vs Unenhanced Images

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OBJECTIVE. We compared the value of contrast-enhanced MR images with that of T2-weighted MR images in the diagnosis and staging of pelvic masses in women.

MATERIALS AND METHODS. The findings on preoperative MR studies of 97 patients with a total of 124 surgically proved lesions were retrospectively analyzed. Unenhanced T1- and T2-weighted spin-echo images were compared with contrast-enhanced T1-weighted images. The final diagnosis included benign (36 patients), borderline (six patients), and malignant (15 patients) ovarian masses, fallopian tube masses (15 patients), endometrial tumors (seven patients), cervical carcinomas (32 patients), subserous leiomyomas (11 patients), and two masses of extragenital origin.

RESULTS. In the depiction of pelvic lesions, the sensitivity of contrast-enhanced MR imaging (96%) was equal to that of unenhanced T2-weighted imaging (97%). Contrast-enhanced images were useful in the definition of intratumoral architecture and tumor borders of 72 adnexal masses, resulting in better determination of malignancy (accuracy, 95%) than on T2-weighted images (85%). Size of viable tumor, differentiation of tumor from retained fluid, and depth of myometrial invasion of six endometrial carcinomas were most reliably shown on contrast-enhanced images. In the evaluation of cervical carcinoma, overall staging accuracy of contrast-enhanced imaging (80%) was slightly inferior to that of T2-weighted imaging (83%). However, contrast-enhanced images improved assessment of parametrial and organ invasion in seven cases in which findings on T2-weighted MR images were equivocal. Administration of contrast material was not helpful in the evaluation of subserous leiomyomas or masses of extragenital origin.

CONCLUSIONS. The findings suggest that when results of unenhanced T1- and T2-weighted MR imaging of pelvic masses are equivocal, contrast-enhanced MR images should be used as supportive and complementary pulse sequences to (1) improve definition of intratumoral architecture and prediction of malignancy in adnexal tumors, (2) stage endometrial carcinoma, and (3) determine tumor extension in cervical carcinoma.

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MR imaging is widely accepted as a useful tool for examining women with known or suspected pelvic tumors. Because of its capacity for producing multiplanar images and its unsurpassed soft-tissue contrast, MR imaging is superior to sonography or CT for determining the extent of uterine masses or the origin of adnexal tumors [1-9]. Limitations of unenhanced T1- and T2-weighted MR imaging are the inability to distinguish viable endometrial carcinoma from debris and to determine infiltration in cervical carcinoma. Recent studies [10-13] in gynecologic patients showed an increase in diagnostic information when IV paramagnetic contrast agents were used. The purpose of this study was to determine the capabilities and limitations of contrast-enhanced T1-weighted MR imaging in the diagnosis of pelvic benign lesions and neoplastic masses in women. The results were compared with those of unenhanced T1- and T2-weighted MR imaging.

Materials and Methods

This retrospective study included 97 consecutive women 19–83 years old (mean, 54 years), with a total of 124 pelvic masses (Table 1). Patients were selected for MR imaging on the basis of (1) showing a suspected pelvic mass on sonograms (all patients with adnexal lesions) and being scheduled for surgery or (2) having a biopsy-proved cervical or endometrial malignant tumor and being scheduled for surgery.

MR images were acquired with a 1.5-T magnet (Gyrosan S15, Philips, Shelton, CT). A multislice, conventional spin-echo sequence was used for all patients. In order to provide uniformity in image acquisition, an axial T1-weighted sequence with a repetition time (TR) of 500 msec and an echo time (TE) of 20 msec was used before and after administration of contrast material. For axial T2-weighted images, a TR of 2000 msec and asymmetric TEs of 20 and 80 msec were used. For patients with suspected cervical carcinoma ($n = 32$), slightly T2-weighted (1100/30,60) sagittal images also were obtained. The slice thickness was 5–7 mm, with a gap of 1.0–1.4 mm.

Immediately after IV administration of gadolinium tetraazacyclododecane tetraacetic acid (Gd-DOTA [Dotarem]; Guerbet SA, Aulnay-sous-Bois, France) in a concentration of 0.1 mmol/kg of body weight [14], T1-weighted axial images were obtained. Coronal ($n = 59$) or sagittal ($n = 38$) images were added, depending on the location of the pelvic mass. Although multiplanar images were obtained in all patients, only axial sequences were evaluated for this study.

MR images were analyzed before surgery. The reader had no knowledge of patients' clinical history, sonographic findings, or pathologic results. Unenhanced T1- and T2-weighted images were compared with contrast-enhanced T1-weighted images. The presence, location, size, intratumoral architecture, and definition of margins of the lesions were studied. The clinical and MR findings were then correlated with the final surgical and pathologic findings. For analysis of signal characteristics, structures and variation of signal intensity within the mass, signal enhancement, and presence of a capsule (thickness and regularity) were classified. In patients with cervical and endometrial carcinoma, tumor extension into the vagina, bladder, rectum, and parametrial tissue was evaluated. In patients with adnexal disease, the criteria reported by Morrow and Townsend [15] were used to decide if a lesion was malignant. Any mass was diagnosed as malignant if it was larger than 4 cm in diameter. A cystic mass was considered malignant if the wall of the mass was more than 3 mm thick or nodules or vegetations were present. Solid masses with or without areas of necrosis were considered malignant. Other criteria indicating that a mass was malignant were infiltration into adjacent organs or into the pelvic sidewall, ascites, lymphadenopathy, and intraabdominal metastases.

As proposed by Stevens et al. [10] and Hricak et al. [11], classification of ovarian, cervical, and endometrial tumors based on MR findings was modified from accepted criteria of the International Federation of Gynecology and Obstetrics (FIGO) [16].

A subjective grading system was used to score the quality of the MR images. Images were suboptimal (grade 1) when motion or peristaltic artifacts led to equivocal definition of tumor location and extension. Images were satisfactory (grade 2) when depiction of the lesion and surrounding tissue was good. Images were optimal (grade 3) when intratumoral architecture and tumor surface were clearly seen and no motion artifacts were present.

Signal intensities were quantified by using operator-defined regions of interest for the mass (solid and cystic portion), adjacent fat, myometrium, endometrium (vaginal wall), normal ovary (if present), and cervical stroma (in patients with cervical and endometrial carcinoma). The data were expressed as a percentage of signal contrast (%C), calculated according to the formula

TABLE 1: Pathologic Findings in 97 Patients with 124 Pelvic Lesions

Findings	No. of Patients
Ovarian masses	
Benign conditions	
Corpus luteum cysts	2
Hemorrhagic corpus luteum cyst	3
Polycystic ovarian disease	1
Serous cystadenoma	15
Serous hemorrhagic cystadenoma	2
Serous cystadenofibroma	1
Mucinous cystadenoma	1
Endometrioma	2
Fibrothecoma	1
Sertoli-Leydig cell tumor	1
Mature cystic teratoma	7
Borderline tumors	
Serous cystadenoma	5
Mucinous cystadenoma	1
Malignant conditions	
Serous cystadenocarcinoma	6
Mucinous cystadenocarcinoma	3
Endometrioid cystadenocarcinoma	2
Granulosa cell carcinoma	1
Recurrent cystadenocarcinoma	1
Breast carcinoma metastasis	2
Total	57
Fallopian tube masses	
Paraovarian cyst	5
Hydrosalpinx	5
Endometriosis	4
Extrauterine pregnancy	1
Total	15
Uterine masses	
Endometrial carcinoma	6
Endometrial polyp	1
Cervical carcinoma	32
Subserous leiomyoma	11
Total	50
Extragenital masses	
Leiomyoblastoma of colon	1
Thrombosed false aneurysm	1
Total	2

Note.—In 21 patients, more than one lesion was found at surgery.

%C = [Intensity of region of interest (I_i)
– Intensity of fat (I_f)/ $I_f + I_i$] $\times$ 100.

Student's t-test was used for statistical analysis. A p value of less than .05 was considered statistically significant.

Of the 97 patients, 46 had hysterectomy with bilateral adnexectomy, 11 had unilateral adnexectomy, three had bilateral adnexectomy, two had dilatation and curettage, two had hysterectomy, three had diagnostic laparoscopy with biopsy, and 11 patients with advanced cervical carcinoma had multiple biopsies. Adnexal cysts were removed in six patients, and myomectomy was done in two. In advanced adnexal disease, hysterectomy, bilateral adnexectomy, and omentectomy ($n = 8$), or pelvic exenteration ($n = 2$) was performed. Autopsy findings were available in one patient. In 15 patients with cervical carcinoma, pelvic lymphadenopathy was performed. Infiltration into the vagina, rectum, or urinary bladder was confirmed by colposcopy, rectoscopy, or cystoscopy, respectively. The histologic findings of adnexal disease were classified according to the classification system devised by the World Health Organization [17].

Surgery revealed a total of 124 pelvic lesions (Table 1). Among the adnexal lesions, 57 (46%) were of ovarian origin, and 15 (12%) were

abnormalities of the fallopian tube. The ovarian abnormalities included 36 benign lesions, six tumors of borderline malignancy, and 15 malignant disorders. Mean size of adnexal masses was 7.8 cm (range, 0.5–28.0 cm).

Of the patients with uterine lesions, six had endometrial carcinoma (four, stage I disease; one, stage II disease; and one, stage III disease), and one had an endometrial polyp. Eleven patients who had subserous leiomyomas of the uterus had been referred for MR imaging because the tumors had been misinterpreted as adnexal masses on sonograms.

Thirty-two patients had cervical carcinoma; 28 (88%) of these patients had squamous cell carcinoma, three (9%) had adenocarcinoma, and one (3%) had a stromal sarcoma. Twelve patients had stage I disease (including eight with stage Ib disease), one had stage IIa disease, eleven had stage IIb disease, four had stage IIIb disease, and four had stage IVa disease. The tumors showed infiltration into the vagina in 10, the parametria in 19, the vulva in one, the urinary bladder in three, the urethra in one, the rectum in one, and the ovary in one. Of the 22 patients in whom pelvic lymph nodes were sampled, malignant lymph nodes were found in nine.

In two patients, surgery revealed masses of extragenital origin; one had a malignant leiomyoblastoma of the colon, and one had a thrombosed false aneurysm of the left external iliac artery.

Results

Adnexal Disease

Two small (0.5 cm) lesions in patients with endometriosis were missed on unenhanced T2-weighted MR images, whereas findings on contrast-enhanced MR images were false-negative in three patients with endometriosis (0.5–1.0 cm).

MR imaging clearly showed the origin of adnexal masses. However, in three patients with diseases of the fallopian tube (one with paraovarian cyst, one with hydrosalpinx, and one with endometriosis of the ligamentum latum), findings on both enhanced and unenhanced MR images were interpreted as masses of ovarian origin.

Contrast-enhanced MR imaging did not improve depiction of adnexal tumors, but it was useful in the definition of intratumoral architecture (differentiation between solid and cystic components) and tumor margins. Serous cystic lesions, like cystadenomas, showed homogeneous low signal intensity on T1-weighted images. Mucinous or hemorrhagic cysts or endometriomas had medium to high signal intensity on both T1- and T2-weighted images. On T2-weighted images, high signal intensity of the cyst resulted in decreased delineation from surrounding fat. Images obtained after administration of Gd-DOTA showed an enhancing smooth, thin wall.

Complex benign ovarian masses with both solid and cystic components (fibrothecoma, cystadenofibroma, and Sertoli-Leydig cell tumor) had thickened walls of medium to high signal intensity and high-intensity cystic components on T2-weighted images. Contrast-enhanced T1-weighted images showed enhancement of solid portions, with excellent depiction of intratumoral architecture and delineation from surrounding fat. On enhanced images, the signal intensity of solid portions was similar to that of normal ovarian tissue (%C, -18 ± 14 ; $p > .05$). With mature cystic teratomas, a characteristic intratumoral chemical-shift artifact was seen on both

T1- and T2-weighted images in four of seven patients. The masses had parts with low (simple cystic), medium (dermoid nipple, wall), or high (fat, debris) signal intensity on T1-weighted images. Gravity-dependent layering of the debris was found in two cases only. Enhancement of the wall was noted in all seven lesions, but in only one of the protrusions (so-called dermoid nipple).

Tumors of borderline malignancy (six) and ovarian carcinomas (15) appeared as large (6–18 cm) masses with irregular walls, septa, papillary projections, and complex cysts (Fig. 1). The different tumor components were evident on both T2-weighted and contrast-enhanced T1-weighted MR images. However, the improved signal contrast between solid, cystic, or necrotic components on contrast-enhanced T1-weighted images resulted again in superior definition of intratumoral architecture and tumor margins. Contrast enhancement in solid portions of malignant masses (%C, -25 ± 15) was not significantly different from that in benign lesions ($p > .05$). Peritoneal metastases were seen in five patients (Fig. 1), and ascites was found in 13. On the basis of criteria of malignancy, 94% of benign and 95% of borderline or malignant lesions were characterized correctly on the basis of contrast-enhanced MR imaging findings. On T2-weighted images, diagnosis of a mass as malignant or benign was correct in 86% of benign and 85% of malignant masses. Improvement in diagnosis with contrast-enhanced imaging was due to better definition of wall thickness, the presence of tumor nodules, and peritoneal metastases and improved assessment of infiltration into adjacent organs.

Fallopian Tube Masses

Fallopian tube masses had features similar to those of ovarian lesions. Hydrosalpinx (Fig. 2) was detected on MR images as a tubular cystic structure in the adnexal region. Soft-tissue contrast was better on contrast-enhanced T1-weighted images than on unenhanced T2-weighted images. In four patients with ovarian lesions, concomitant endometrial lesions (0.5–1.5 cm) on the uterine surface, cul-de-sac, or ligamentum latum were found at surgery. T2-weighted images showed two of the four lesions, and contrast-enhanced images showed one. Ectopic pregnancy was shown as a complex solid and cystic lesion with concomitant ascites and was misclassified as a malignant adnexal mass.

Subserous Leiomyomas

Leiomyomas had low homogeneous or inhomogeneous signal intensity on both T1- and T2-weighted MR images (Fig. 3). Degenerative changes within the mass were seen best on T2-weighted images. On contrast-enhanced T1-weighted images, the isointensity of myoma and myometrium suggested the uterine origin of the lesions.

Endometrial Carcinoma

In the evaluation of endometrial masses, diagnosis of tumor (including one polyp) based on T2-weighted and contrast-

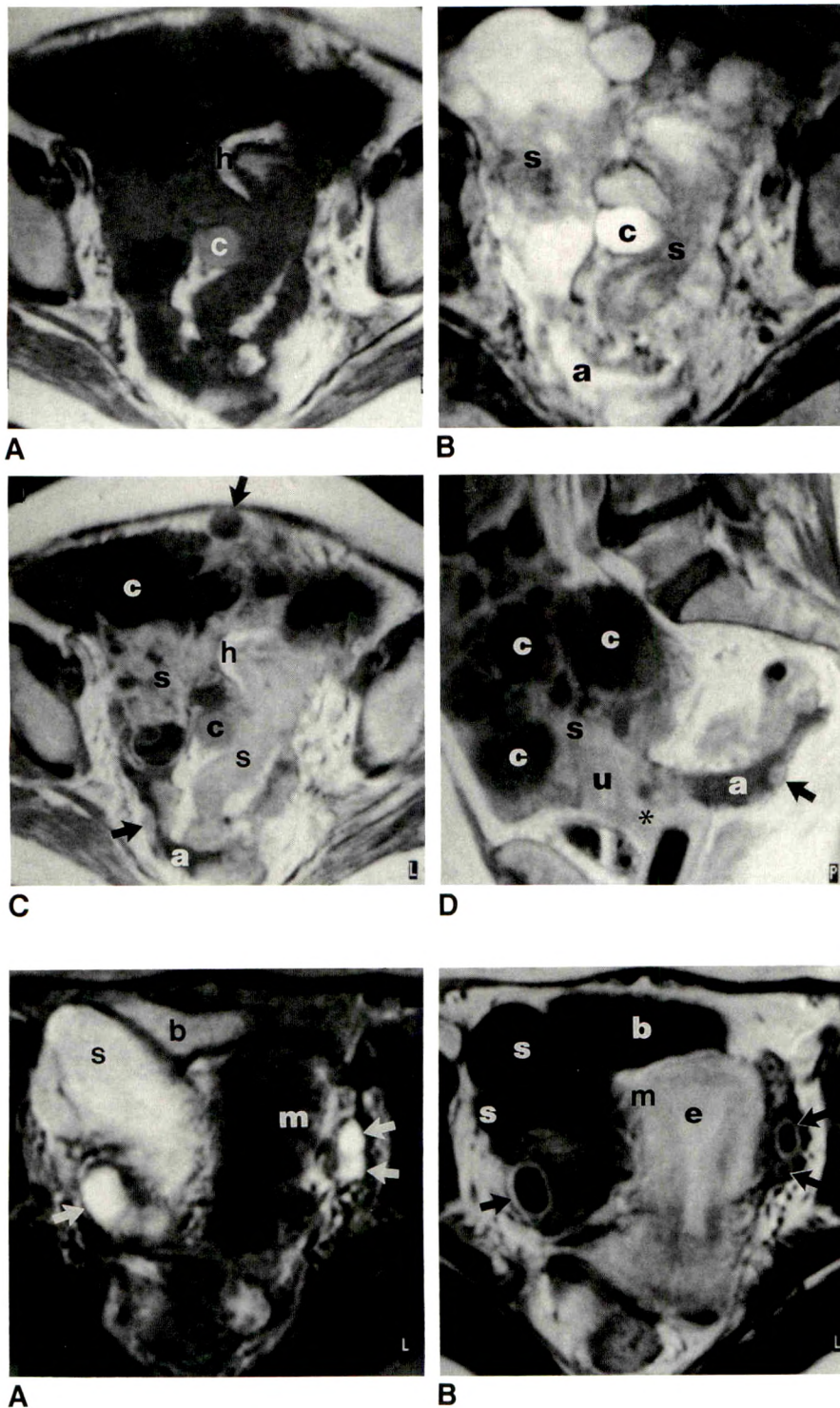


Fig. 1.—A–D, Poorly differentiated endometrioid cystadenocarcinoma of ovary, stage IIc disease. Axial T1-weighted (500/20, A), T2-weighted (2000/80, B), contrast-enhanced T1-weighted (500/20, C), and sagittal contrast-enhanced T1-weighted (500/20, D) MR images show a large complex pelvic mass with cystic (c), solid (s), and hemorrhagic (h) components. Note infiltration into Douglas pouch (asterisk) and multiple peritoneal and omental metastases (arrows). Small amount of ascites (a) is present. Optimal delineation of intratumoral and peritumoral architecture is achieved on the contrast-enhanced images, whereas details are partially obscured on T2-weighted images. Nevertheless, correct diagnosis was made on the basis of both sequences. u = uterus.

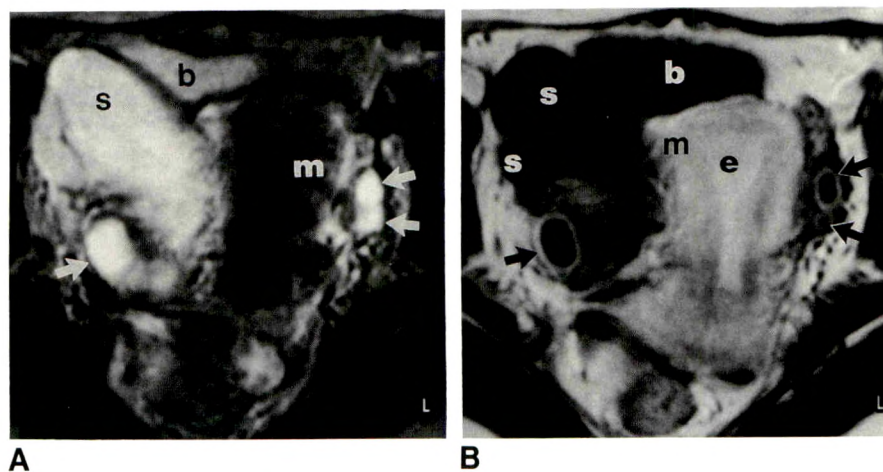


Fig. 2.—A and B, Hydrosalpinx of right fallopian tube. Axial T2-weighted (2000/80, A) and contrast-enhanced T1-weighted (500/20, B) MR images show multiple, sharply defined tubular structures (s) in right adnexal region, adjacent to uterus. Ovaries contain small cysts (arrows) with benign characteristics. T2-weighted images (A) shows less definition of hydrosalpinx and uterus. Note delineation of uterine zonal anatomy on contrast-enhanced images (B). e = endometrium, m = myometrium, b = urinary bladder.

enhanced MR images was correct in all cases. The tumors were seen as structures with inhomogeneous medium to high signal intensity within the endometrial cavity on T2-weighted images. On images obtained after administration of contrast material, medium to high signal intensity of solid tumor components was noted; retained mucus or blood products did

not show enhancement (Fig. 4). Thus, better definition of tumor size and differentiation from retained fluid was achieved on the contrast-enhanced images. The endometrial polyp was misclassified as a malignant mass on both enhanced and unenhanced images. The use of Gd-DOTA improved tumor detection and staging accuracy. On T2-weighted images,

Fig. 3.—A and B, Subserous leiomyoma of uterus. Axial T2-weighted (2000/80, A) and contrast-enhanced T1-weighted (500/20, B) MR images show a large relatively homogeneous, comma-shaped mass (t) displacing uterus to right. Signal intensity and contrast enhancement of mass parallel that of myometrium (m) on all pulse sequences. Note dilated left uterine vessels (arrow), which are best seen on contrast-enhanced image (B).

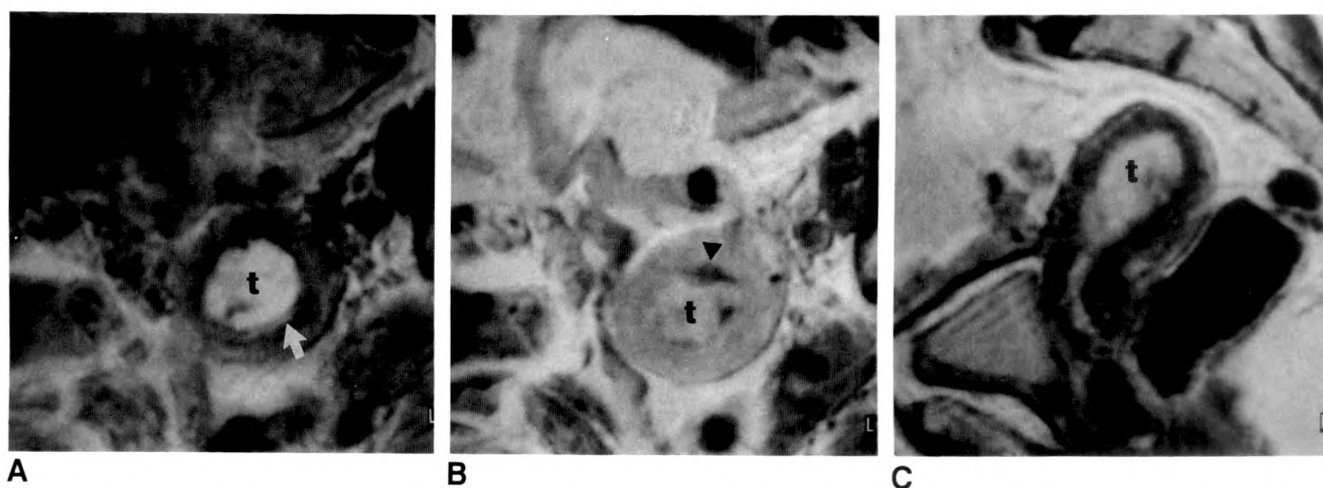
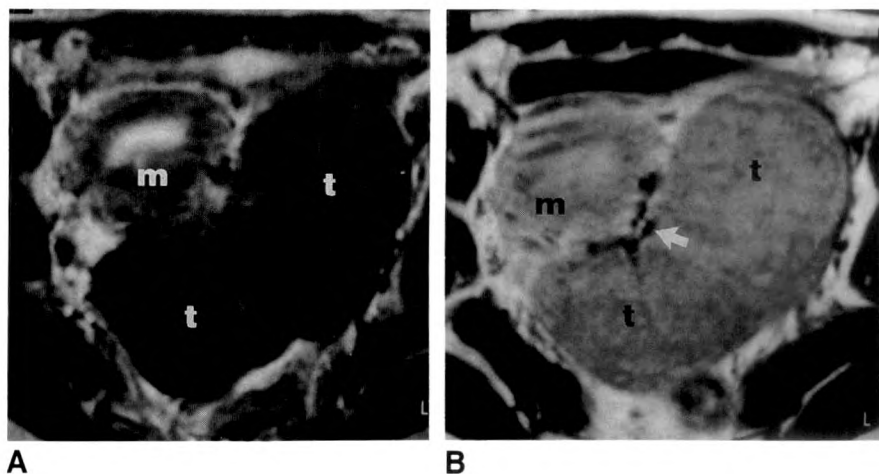


Fig. 4.—A–C, Endometrial carcinoma, stage Ia disease. Axial T2-weighted (2000/80, A), contrast-enhanced T1-weighted (500/20, B), and sagittal slightly T2-weighted (1100/60, C) MR images show mass (t), confined to endometrial cavity. On T2-weighted images (A and C) mass appears inhomogeneous with partial interruption (arrow) of junctional zone, suggesting superficial myometrial invasion. Contrast-enhanced image (B) allowed correct assessment of tumor's size, location, and stage. Enhancing tumor (t) is clearly delineated from nonenhancing retained fluid (arrowhead), and no myometrial invasion is seen.

tumor size was overestimated in three patients and myometrial invasion in two; contrast-enhanced images showed false-positive myometrial infiltration in one patient only (Fig. 5).

Cervical Carcinoma

Of 32 lesions, two small carcinomas (stage Ia disease) were missed on both contrast-enhanced and unenhanced T2-weighted MR images. On unenhanced T1-weighted images, the low signal intensity of tumors ($\%C, -50 \pm 7$) allowed excellent delineation from surrounding fat, whereas the high signal intensity of the carcinoma on T2-weighted images resulted in good contrast to cervical stroma and myometrium. However, motion and bowel peristaltic artifacts made assessment of tumor extension difficult on T2-weighted images in seven patients. Images obtained after administration of Gd-DOTA showed inhomogeneous moderate to high signal enhancement of the tumor ($\%C, -19 \pm 14$) in contrast to minimal

enhancement of cervical stroma. In six patients, high signal intensity of myometrium, endometrium, or vaginal mucosa resulted in poor tumor contrast, and tumor size was overestimated or staging was inaccurate. Of 32 patients, 19 showed parametrial infiltration at surgery. In the evaluation of parametrial involvement, findings on contrast-enhanced imaging were true-positive in 16, true-negative in 10, false-positive in three, and false-negative in three. These findings resulted in improved sensitivity but lower specificity for contrast-enhanced images compared with T2-weighted images.

In the assessment of tumor infiltration into the vagina (10 cases), vulva (one), rectum (one), bladder (three), urethra (one), and ovary (one), contrast-enhanced MR imaging was superior to unenhanced T2-weighted imaging in four of 17 patients. In these cases, evidence of infiltration was equivocal on T2-weighted images but could be seen more reliably on contrast-enhanced images (Fig. 6). In two patients, tumor infiltration was overestimated on the basis of contrast-en-

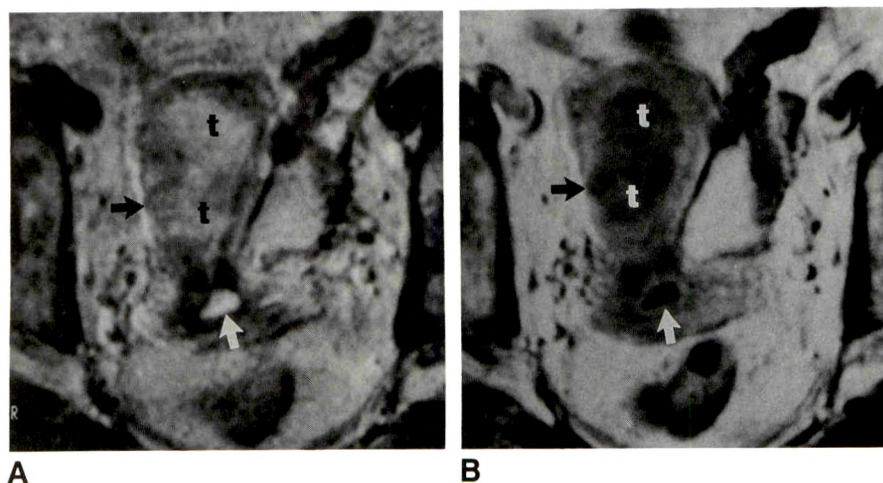


Fig. 5.—A and B, Endometrial carcinoma, stage IIa disease. Axial T2-weighted (2000/80, A) and contrast-enhanced T1-weighted (500/20, B) MR images show large endometrial mass (t) with deep invasion (black arrows) of myometrium and extension into cervical canal. Note fluid-containing deep ulcer (white arrows) in cervix. Superior assessment of mass and staging was obtained with contrast-enhanced image (B).

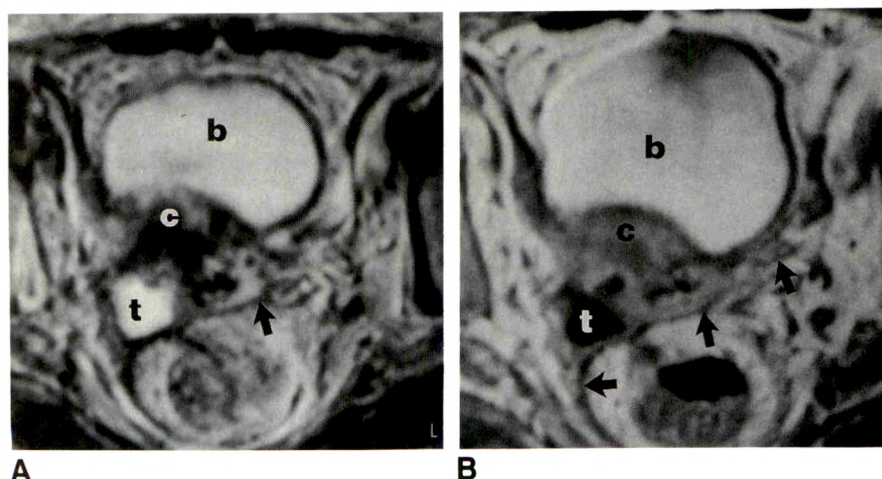


Fig. 6.—A and B, Squamous cell carcinoma of cervix, stage IIb disease. Axial T2-weighted (2000/80, A) and contrast-enhanced T1-weighted (500/20, B) MR images show irregular necrotic tumor (t) of cervix with extension in corpus uteri (c), and both parametria (arrows). T2-weighted image (A) shows poor definition of tumor extension. On contrast-enhanced image (B), parametrial invasion is clearly seen as enhancing structures (arrows) isointense with respect to cervical tumor. Large area of tumor necrosis has high signal intensity on T2-weighted image (A) and remains hypointense on contrast-enhanced image (B). Assessment of invasion in posterior wall of urinary bladder (b) is difficult on T2-weighted image (A), and invasion can better be ruled out on the basis of contrast-enhanced image (B).

hanced MR imaging (mucosal enhancement was misinterpreted as tumor involvement). Overall staging accuracy with T2-weighted images (83%) was slightly superior to that with contrast-enhanced images (80%).

Extragenital Masses

The leiomyoblastoma of the colon appeared as a large pelvic mass, located in the rectal fossa, with displacement of the uterus and urinary bladder anteriorly. On the contrast-enhanced T1-weighted images, superior soft-tissue contrast was achieved. The thrombosed false aneurysm had characteristic features on MR images due to flow artifacts and high-signal-intensity thrombus. Administration of Gd-DOTA was of no advantage in this case.

Discussion

The usefulness of MR imaging in the evaluation of pelvic masses has been stressed in several previous reports [1–9]. Nevertheless, unenhanced MR imaging has certain limitations. For instance, overlapping signal intensities of the ovary,

small cystic adnexal lesions, and surrounding fat may result in low tumor-to-adnexa and adnexa-to-fat contrast. In the definition of tumor origin in adnexal disease, or differentiation of viable from necrotic tumor in endometrial carcinoma, unenhanced MR imaging has not yet fulfilled its potential.

The results of this study indicate that Gd-DOTA-enhanced T1-weighted MR imaging is useful in the assessment of adnexal masses. However, use of contrast-enhanced MR imaging did not improve detection of small tumors. Among 72 adnexal lesions, three small lesions in patients with endometriosis were missed, resulting in an overall detection rate of 96%. These findings confirm results of other series that had an overall sensitivity of 87–100% but a poor sensitivity for depicting endometrial lesions [1, 2, 10, 18]. In cystic adnexal lesions, contrast-enhanced T1-weighted MR imaging was superior to T2-weighted MR imaging, because differences in the signal intensity of serous, mucinous, or hemorrhagic fluid and surrounding fat were most pronounced on T1-weighted MR images. However, distinction between blood and lipid was difficult with both MR sequences. Recently, Kier et al. [19] reported that MR imaging with fat-suppression techniques is useful in the differential diagnosis of hemorrhagic vs lipid-containing masses. The administration of Gd-

DOTA improved the assessment of complex masses. On T2-weighted MR images, cystic and solid portions frequently showed similar signal intensities, resulting in poor depiction of intratumoral architecture. Although these findings are consistent with the observations of Stevens et al. [10], Ghossain et al. [20] found a clear distinction between cystic and solid parts of a tumor on both T1- and T2-weighted MR images. These findings may be related to the lower magnetic field strengths used in their study (0.5 T vs 1.5 T).

Previous studies pointed out some limitations of using findings on MR images to predict malignancy of ovarian masses. When the ancillary criteria were used, characterization of masses was correct in 85% on T2-weighted MR images. Because depiction of intratumoral architecture and tumor definition was improved on contrast-enhanced images, accuracy (95%) was superior to that with unenhanced images. Even though malignancy can be suspected when the wall of a tumor is irregular or invasion of adjacent organs, ascites, or intraabdominal spread of disease is evident, findings on contrast-enhanced MR imaging may still be false-positive or false-negative. The degree of contrast enhancement was moderate in solid tumors and in solid components of complex lesions and variable among tumors of different types and of the same type. Thus, the pattern of enhancement of different tumors was nonspecific, and determination of malignancy based on signal enhancement was not possible. The potential of MR imaging in the diagnosis of peritoneal metastases could not be assessed, because the upper abdomen was not examined in this series.

The ability of MR imaging to produce images in a multiplanar fashion is a major advantage in determining the site of tumor origin [1, 3, 9]. In the present study, both T2-weighted and contrast-enhanced MR imaging allowed correct determination of tumor origin in 96% of cases. Because of their classical appearance, subserous leiomyomas were easily diagnosed on the basis of findings with both pulse sequences [3]. Administration of contrast material did not improve diagnostic accuracy in this respect.

Endometrial carcinomas had a variable appearance on unenhanced T2-weighted MR images. Hyperplasia, submucosal leiomyoma, and blood clots may increase endometrial thickness or widen the uterine cavity, simulating endometrial carcinoma [8, 9]. In the present study, administration of Gd-DOTA was advantageous. The contrast between carcinoma and normal endometrium was accentuated, and detection of small tumors confined to the endometrium was possible on the contrast-enhanced images. Superior differentiation of tumor from retained fluid resulted in an overall improvement in staging accuracy. Furthermore, the contrast-enhanced sequences allowed better assessment of myometrial invasion. Although the number of patients investigated in this study was too small for statistical purposes, the preliminary data already corroborate the results of Hricak et al. [11].

In the evaluation of cervical carcinoma, accurate determination of size, location, and presence of infiltration into adjacent organs has a strong impact on treatment choice between surgery and radiation therapy. Early reports have shown a distinct advantage of MR imaging over clinical FIGO staging in the assessment of tumor invasion into the parametria,

pelvic sidewall, lower uterine segment, and retroperitoneal nodes. These seem to be a tendency toward overstaging and low sensitivity in the evaluation of urinary bladder invasion on T2-weighted images [4-7]. Recently, Hricak et al. [11] found prospectively that the depth of stromal and parametrial invasion was consistently overestimated on the basis of contrast-enhanced MR imaging. Congestion and edema of peritumoral cervical stroma showed contrast enhancement and were frequently misclassified as tumor infiltration.

In agreement with their findings [11], assessment of tumor invasion on contrast-enhanced images was inferior to that on T2-weighted images in six patients in this study. However, this study revealed some advantages of contrast-enhanced MR imaging. On T2-weighted images, accentuated motion artifacts or image distortion led to suboptimal delineation of tumor borders in seven patients (Figs. 1, 4, and 5). Because of the better image quality of contrast-enhanced images, definition of the extent of the mass was improved in these seven cases. Administration of contrast material was particularly useful in the evaluation of parametrial or urinary bladder invasion in which findings on T2-weighted images were equivocal.

When conventional spin-echo sequences are used, acquisition of a set of T2-weighted and unenhanced and contrast-enhanced T1-weighted images requires up to 1 hr. The results of this study suggest that in the evaluation of adnexal and endometrial masses, and selected cases of cervical carcinoma, MR imaging can be limited to unenhanced and contrast-enhanced T1-weighted images, without loss of accuracy. Thus, a significant shortening of imaging time may result. On the other hand, recently introduced fast pulse sequences (like fast or turbo spin-echo) have shown equal lesion detection but significant reduction of imaging time (Smith RC et al., presented at The Radiological Society of North America meeting, December 1991). Preliminary results with a dynamic technique using gradient-echo pulse sequences after bolus injection of contrast material have been described by Hirano et al. [21]. They found that the dynamic sequence was helpful in the staging of uterine neoplasms, particularly in the evaluation of myometrial invasion of endometrial carcinomas. However, the precise roles of both of these promising new imaging techniques remain to be elucidated.

In summary, results of this study support previous observations that contrast-enhanced MR imaging may be useful in the assessment of pelvic lesions in women. In comparison with T2-weighted MR images, contrast-enhanced T1-weighted images provide (1) improved assessment of intratumoral architecture and determination of extension and malignancy in adnexal masses, (2) improved staging accuracy and superior delineation of tumor vs necrosis of endometrial carcinoma, and (3) possibly, improved assessment of parametrial and organ invasion in cervical carcinoma when results of T2-weighted imaging are equivocal. As a consequence, contrast-enhanced MR imaging should be considered a valuable supportive and complementary sequence to unenhanced imaging in the evaluation of pelvic masses.

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Case Report

Adnexal Torsion: Diagnosis by Using Doppler Sonography

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Torsion of the ovary, and rarely the fallopian tube, is a known cause of acute abdominal pain, especially in postpubertal females. This condition requires rapid surgical intervention to save the ovary. If diagnosis is delayed, other complications such as peritonitis and even death may result [1, 2]. It has been theorized that Doppler sonography of the adnexal vessels may facilitate the diagnosis of ovarian torsion by showing a lack of blood flow to the ovary, due to the mechanical torsion of the ovarian vessels [3]. To our knowledge, however, no reports of Doppler assessment in proved cases of adnexal torsion have been published. We report the Doppler findings in a patient with surgically proved adnexal torsion and note the findings in two others. All three patients had normal adnexal Doppler arterial waveforms and resistive indexes.

Case Report

A 22-year-old woman (gravida 3, para 2, aborta 1, last menstrual period 5 days before evaluation) had 5 days of increasing pain in the right lower quadrant of the abdomen, nausea, and vomiting. On pelvic examination, a 7-cm right-sided adnexal mass was noted. Pelvic sonography, using both transabdominal and transvaginal probes, revealed a well-defined heterogeneous predominantly solid mass in the right adnexa, measuring 5.8 × 8.4 × 7.0 cm (Fig. 1). A moderate amount of free intraperitoneal fluid was present in the cul-de-sac. Pulsed Doppler evaluation of the ovarian artery showed a normal waveform, with a normal resistive index of 0.72. Sonographic findings

were suggestive of adnexal torsion. Laparotomy revealed a hemorrhagic right-sided adnexal mass with 720° torsion of the fallopian tube. A right-sided salpingo-oophorectomy was performed. The final pathologic diagnosis was hemorrhagic necrosis of the ovary consistent with torsion.

Discussion

In addition to the case described, we saw two other cases of adnexal torsion with normal Doppler arterial waveforms. These two cases were surgically proved.

When adnexal masses are evaluated with Doppler imaging, it is important to evaluate flow within the mass. If Doppler examination is performed near the edge of the adnexal mass, vessels in the pelvic side wall that are unrelated to the ovary may be misinterpreted as reflecting flow to the mass. Vessels in the pelvic side wall arise from the internal iliac artery and have high-resistance waveforms without prominent diastolic flow.

It has been theorized that Doppler sonography may facilitate the specific diagnosis of ovarian torsion by revealing lack of blood flow to the ovary. Certainly, color Doppler sonography has been shown to play a decisive role in the diagnosis of testicular torsion in men. It is interesting that in our group of three patients with surgically proved adnexal torsion, all had normal adnexal Doppler arterial waveforms and resistive indexes.

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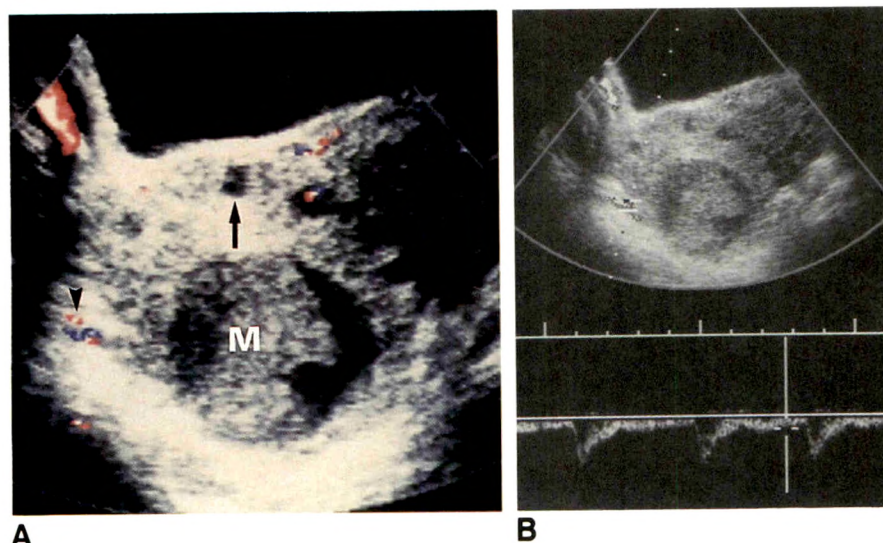


Fig. 1.—22-year-old woman who had pain in right lower quadrant for 5 days. Laparotomy revealed 720° torsion of right fallopian tube.

A, Transverse transabdominal color Doppler sonogram of twisted right adnexa shows a well-defined mass (M) within ovary, corresponding to clotted blood within a cyst. Many small, well-defined anechoic follicles (arrow) are visible at edge of enlarged ovary. Color Doppler signals are seen within ovarian parenchyma and in ovarian artery (arrowhead).

B, Pulsed-wave duplex Doppler sonogram of ovarian artery shows a normal waveform, with a normal resistive index of 0.72

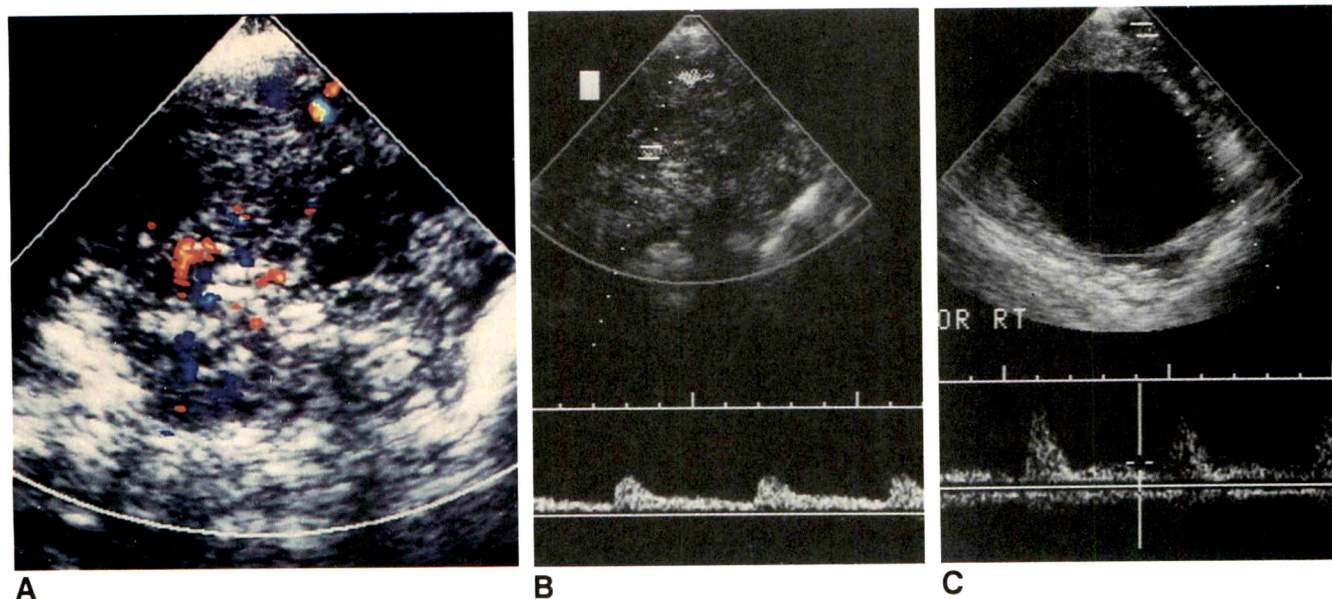


Fig. 2.—23-year-old woman who had nausea, vomiting, and pain in right lower quadrant for 2 days. Laparotomy revealed torsion of right fallopian tube. A, Coronal transvaginal sonogram shows "solid" component of large, complex, twisted fallopian tube. Pathologically this was found to consist of blood dissecting through fat. Within blood clot, multiple markedly dilated engorged venous channels were found. "Solid" component reveals flow by color Doppler assessment.

B, Pulsed-wave duplex Doppler sonogram shows a normal waveform, with a normal resistive index of 0.67.

C, Pulsed-wave duplex Doppler sonogram at edge of cystic component shows a normal waveform, with a normal resistive index of 0.74.

Adnexal torsion occurs predominantly in women of reproductive age. Predisposing factors include nonadherent adnexal masses, found in 50–81% of patients with adnexal torsion [1, 4]. The overall prevalence of torsion as the presenting manifestation of an adnexal mass, most commonly benign cystic teratoma, is 7%. Pregnant women have a greater risk of torsion of adnexal masses than nonpregnant women do. Torsion of a normal ovary is more common in younger females, in whom the adnexa are especially mobile,

allowing torsion at the mesosalpinx [5]. Patients with ovarian hyperstimulation due to treatment with infertility drugs (ovarian hyperstimulation syndrome) who become pregnant have a greater risk of adnexal torsion (16%) than do those women who do not become pregnant [2]. Acute changes in intraabdominal pressure, for example from lifting or pushing heavy objects, have been implicated as a factor in adnexal torsion.

A spectrum of ischemic changes due to adnexal torsion is noted in the ovary. The amount of damage depends on the

extent of vascular compromise. First, the venous flow and lymphatic return are blocked, along with continued arterial perfusion of the adnexa, leading to diffuse enlargement and edema of the ovarian parenchyma and often to peripheral follicular distension due to transudation of fluid into the cysts. With further passage of time, continued edema and increased pressure on the twisted pedicle will cause venous occlusion followed by arterial thrombosis. Free fluid is found in one third to two thirds of patients. A spectrum of abnormal findings has been identified in patients with adnexal torsion, from massive ovarian edema to ovarian necrosis.

Arterial Doppler signals were observed in twisted adnexa in all three of our cases. Possible explanations for these observations include the following: (1) venous thrombosis due to torsion leads to symptoms and ovarian necrosis before arterial thrombosis occurs, and (2) persistent adnexal arterial flow is related to the dual ovarian arterial blood supply (the ovarian artery from the aorta, and the ovarian artery branches from the uterine artery that run in the infundibulopelvic ligament).

Despite prior theoretical suppositions of lack of arterial flow

in adnexal torsion, arterial Doppler signal was present in the adnexa of all three of our patients. A prospective study of a larger group of patients, including examination of flow, both arterial and venous, is necessary to determine the role of Doppler sonography in the diagnosis of adnexal torsion.

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Polyethylene Osteolysis

Felix S. Chew and Michael H. Lev¹

A 66-year-old man presented with failure of a total hip replacement 5 years after implantation. Radiographs showed a loose, rotated acetabular component and adjacent osteolysis (Fig. 1). The prosthesis was retrieved and the arthroplasty was revised. The space between the components and the bone was filled with foreign-body granulation tissue. Microscopic examination of this membrane of synovial-like tissue revealed embedded particles of polyethylene that had been engulfed by foreign-body giant cells. The material removed from the region of adjacent osteolysis was identical. There was no evidence of infection or tumor. The final pathologic diagnosis was foreign-body response to polyethylene with osteolysis leading to loss of component fixation.

Nearly all modern total joint prostheses have a metal component that articulates with a plastic (usually ultrahigh molecular weight polyethylene) bearing surface. In hip prostheses, a polyethylene liner is set into a metal cup that is secured to the acetabulum either by cement or by biologic ingrowth into a porous coat. A metallic femoral component articulates with the polyethylene liner. Mechanical friction between the components during movement wears small (1–4 μm) particles away from the polyethylene surface. This debris incites a foreign-body granulomatous reaction that induces localized bone resorption [1, 2]. Migration of this debris and its accompanying reaction along cement–bone or metal–bone inter-

faces of acetabular components, usually in the form of a thin membrane, may lead to loosening over a period of years [2, 3]. This process may be observed radiographically as a thin zone of radiolucency. When massive localized osteolysis occurs in adjacent bone, the lesions are filled with the same polyethylene debris and foreign-body granulation tissue that cause component loosening [4]. Polyethylene debris transported through lymphatic channels can incite the foreign-body reaction in regional lymph nodes [5].

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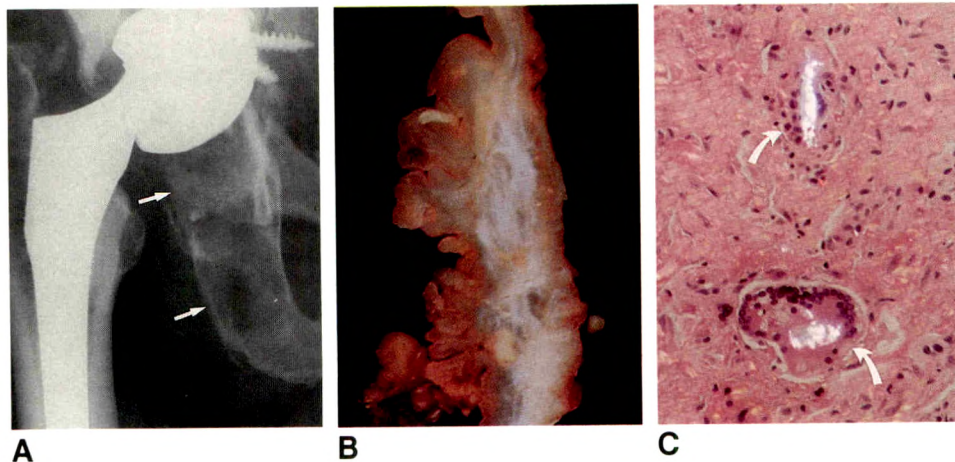


Fig. 1.—Polyethylene osteolysis. A, Radiograph shows loose, rotated acetabular component and osteolysis of the adjacent pelvis (arrows).

B, Cut surface of membrane removed at surgery from around the prosthesis shows papillary hyperplasia (left side) that faced the metal components, and a smoother side that abutted the bone (approximate specimen length is 2 cm).

C, Photomicrograph (polarized light) shows refractile polyethylene particles within the cytoplasm of foreign-body giant cells (arrows).

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Detection of Acute Avascular Necrosis of the Femoral Head in Dogs: Dynamic Contrast-Enhanced MR Imaging vs Spin-Echo and STIR Sequences

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OBJECTIVE. Spin-echo MR imaging has been shown to be highly sensitive in the detection of avascular necrosis. Very early avascular necrosis can, however, appear normal on MR images. We compared dynamic contrast-enhanced MR imaging with conventional spin-echo and short TI inversion-recovery (STIR) sequences for detecting acute osteonecrosis in an animal model.

MATERIALS AND METHODS. Avascular necrosis was induced unilaterally in the femoral heads of five dogs that were imaged with a 1.5-T system within 3 hr of devascularization. After standard T1-weighted, T2-weighted, and STIR images, gradient-recalled echo images, 28/5 (TR/TE) with a 45° flip angle, were obtained at 6-sec intervals for 90 sec synchronous with the IV administration of 0.2 mmol of gadoteridol per kilogram of body weight at a rate of 2 ml/sec via an automated injector. Two animals were reimaged after 7 days.

RESULTS. Spin-echo and STIR images did not show any acute changes in the ischemic femoral heads. In contrast, significant differences were present in the enhancement profiles of the marrow spaces in the normal and ischemic femoral heads ($p = .005$). Normal marrow was characterized by rapid enhancement, with an average signal intensity increase of 83% peaking at 36 sec; no measurable enhancement was seen in the marrow of the ischemic femoral head. Spin-echo images, obtained 7 days after devascularization ($n = 2$), showed changes characteristic of avascular necrosis. Dynamic contrast-enhanced MR images showed persistent lack of enhancement in the avascular marrow of the ischemic femoral head. A junctional zone, characterized by rapid contrast enhancement in excess of 120% without early washout, was identified at the interface between normal and avascular marrow.

CONCLUSION. In this experimental model, dynamic contrast-enhanced MR imaging proved significantly more sensitive than conventional spin-echo and STIR imaging in the detection of acute avascular necrosis.

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Osteonecrosis is seen with increasing frequency in young adults, reflecting prolonged survival of certain populations at increased risk for this recalcitrant process. Although the debate about optimal treatment options continues, the consensus is that early diagnosis improves prognosis and may prevent severe disability [1-10]. MR imaging has been shown to be the most sensitive and specific imaging technique for detecting avascular necrosis (AVN) [3-7, 11, 12]. Characteristic abnormalities in the marrow of the osteonecrotic femoral head include foci of decreased signal intensity on T1-weighted images [2, 8, 10, 13, 14] and a characteristic double-line sign on T2-weighted images [15]. Bone with histologically proved AVN can, however, appear normal on T1- and T2-weighted MR images [16-18]. Speer et al. [17] were unable to predict AVN on the basis of T1- and T2-weighted spin-echo (SE) images in 15 patients with subcapital fractures of the femoral neck.

Osteonecrosis indicates that ischemia of the cellular constituents of bone and marrow has occurred [1]. Although cessation of blood flow may be initiated in the

arterial, capillary, sinusoidal, or venous vascular network, eventually arterial blood flow will be compromised [1]. The pathophysiology of the disease suggests that assessment of arterial perfusion of the femoral head is the key to earliest diagnosis of AVN.

Using a canine model of AVN (Malizos KN, Quarles LD, Seaber AV, unpublished data) in the femoral head, we compared standard SE and short T1 inversion-recovery (STIR) MR images with dynamic contrast-enhanced MR images for the detection of acute osteonecrosis.

Materials and Methods

Five mature mongrel dogs weighing between 25 and 30 kg were anesthetized and underwent devascularization of the right femoral head for this study, which was approved by our Animal Care and Use Committee. Throughout the study the animals were monitored closely by our veterinary staff. Within 3 hr of the surgery, MR imaging of both hind legs was performed. Subsequently, oxytetracycline was administered IV. Three dogs were sacrificed after 3 days. The remaining two animals were reimaged after 7 days and subsequently sacrificed. All 10 femoral heads were extracted, coronally sectioned, and analyzed for fluorescence.

Femoral Head Devascularization

Under general anesthesia with pentobarbital and halothane, the right hip was approached through a posterolateral incision under aseptic conditions. The biceps femoris muscle was reflected caudally, and the superficial gluteal muscle was detached from the femur. All soft-tissue attachments of the greater trochanter and the intertrochanteric notch were elevated by electrocautery, tagged, and retracted. The capsular insertion of the femur also was cut, and the ligamentum teres was sectioned to allow dislocation of the femoral head. The iliopsoas insertion to the lesser trochanter was protected. After dissection, a rubber tube was coiled around the femoral neck and liquid nitrogen was circulated through the tube for 3 min. During freezing, the surrounding soft tissues were adequately protected with insulating pads. After thawing, the hip capsule was prepared to secure the reduced femoral head into the acetabulum. All of the abductor muscles, the external rotator muscles, and the origin of the vastus lateralis muscle were reattached with absorbable suture loops passed around but not through the bone. After copious irrigation with saline and bacitracin, the surgical wound was closed in layers. Ani-

mals were treated with an antibiotic (cefazolin, 30 mg/kg IV; Lemmon Co., Sellersville, PA) for prophylaxis. During the postoperative period, all animals were free to run in their kennels. The animals were closely monitored, and the analgesic butorphanol tartrate (Aveco Co., Fort Dodge, IA) was administered by a veterinarian as needed.

Histologic Examination

To study the vascularity of the femoral head and neck after devascularization, oxytetracycline (25 mg/kg body weight per day) was administered to all animals postoperatively. Tetracycline is deposited onto the osseous trabeculae and is visualized by fluorescence microscopy. Its deposition depends on absorption, osteoblastic activity, and adequate circulation to the bone. At sacrifice after 3 days ($n = 3$) and after 7 days ($n = 2$), both femora were extracted and placed in 70% alcohol for 48 hr for tissue fixation. Samples were then imbedded in methacrylate and cut with a heavy-duty microtome in complete sections in the coronal plane (5 and 20 μ m thick). A histomorphologic examination under transmitted ultraviolet and polarized light was made of all available sections.

MR Imaging

MR images were obtained with a 1.5-T cryogenic imaging system (Signa, GE Medical Systems, Milwaukee, WI). The dogs were positioned in the left lateral decubitus position in the center of a standard-quadrature head coil. The femora were in the physiologic position perpendicular to the torso. Axial T1-weighted (500/20 [TR/TE]) and T2-weighted (2000/40–80) SE and STIR (2000/40/160 [TR/TE/TI]) images were obtained through the hind legs of the animals. Spatial saturation bands were placed inferiorly and superiorly. A 256×128 imaging matrix, a 24-cm field of view, a section thickness of 5 mm, and one excitation were used.

Two axial imaging locations containing both femoral heads and femoral necks were identified. Synchronous with the IV administration of 0.2 mmol of gadoteridol (ProHance, Squibb Diagnostics, Princeton, NJ) per kilogram of body weight at a rate of 2 ml/sec by an automated injector (MedRad, Pittsburgh, PA), sequential multiphase gradient-recalled echo images (28/5, 45° flip angle) were obtained at the two previously identified locations. The short repetition time ensured high temporal resolution; the 45° flip angle and very short echo time resulted in relatively good T1 weighting. For each of the two locations, 15 sequential images were obtained at 6-sec intervals.

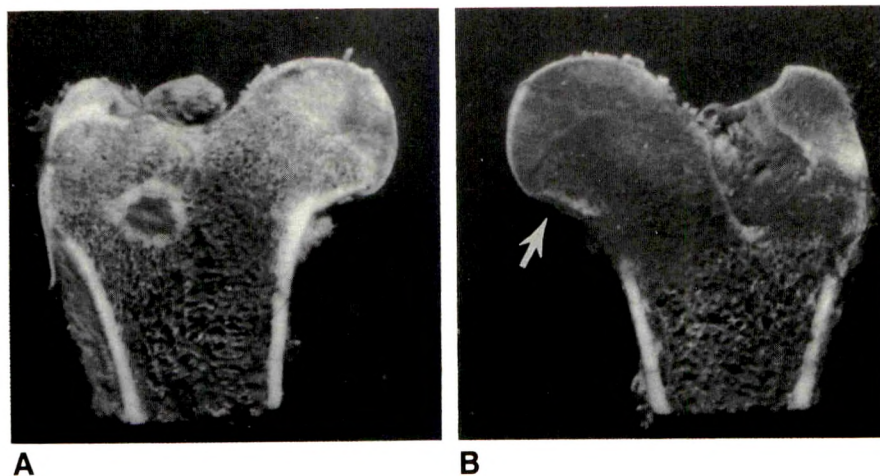


Fig. 1.—Coronal sections of proximal ischemic right femur and normal left femur from an animal sacrificed 3 days after surgery. Absence of fluorescent tetracycline in ischemic right femoral head (arrow) confirms lack of bone viability.

Image Analysis

Quantitative image analysis consisted of signal-intensity (SI) determinations and T2 relaxation time calculations based on regions of interest (ROIs) measuring 4×4 mm and containing 20 pixels.

For analysis of the T1- and T2-weighted and STIR images, ROIs were placed in the marrow space of the femoral heads bilaterally. To compensate for field inhomogeneities, internal reference SI measurements were obtained in the adductor muscle group adjacent to the proximal femur bilaterally. For purposes of comparative analysis, relative SIs were expressed as a ratio of marrow SI to adjacent muscle SI. T2 relaxation time calculations were based on a dual-echo image and the formula,

$$T2 = (TE_2 - TE_1) / \ln (SI_1/SI_2),$$

where TE_1 is 40 msec and TE_2 is 80 msec. Student's t-test was used to compare the relative SIs and T2 relaxation time calculations for T1-weighted, T2-weighted, and STIR images of the avascular right femur and the normal left femur.

Quantitative analysis of the dynamic enhancement images was based on SI measurements for each ROI in each of 15 images

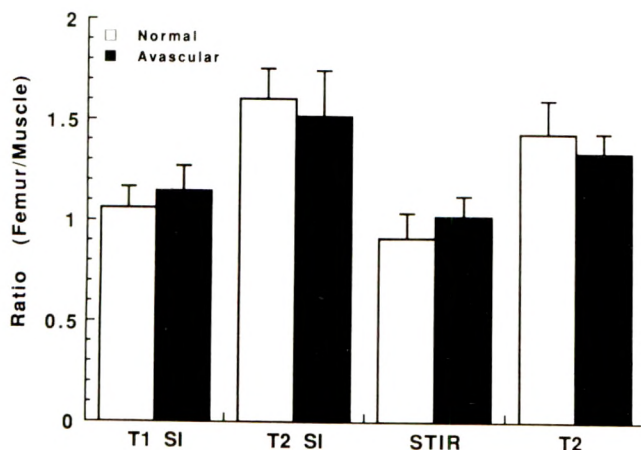


Fig. 2.—Femoral head/muscle signal intensity (SI) ratios for marrow cavities in normal left femoral head and avascular right femoral head failed to show any statistically significant difference on T1-weighted images, T2-weighted images, and STIR images. T2 times in marrow of normal and avascular femoral heads relative to those in adjacent muscle also failed to show any significant difference. Single standard errors are indicated by bars.

obtained in 90 sec. ROIs were placed in the marrow space of the femoral heads in locations identical to those on the SE images and in the right paraspinal muscle.

By using the lowest SI value as the null baseline, we plotted SI measurements of each of the three ROIs against time. The contrast enhancement of the ischemic femoral head, expressed as percent increase in SI, or $[(SI - SI_0)/SI_0] \times 100$, where SI_0 is the baseline value before injection, was compared with that of the normal femoral head for all five animals.

Images of two animals obtained 7 days after surgery were quantitatively analyzed in an identical fashion. For the dynamic contrast enhancement images, two additional ROIs were placed in the right femur: one in the normal marrow of the femoral shaft and one in a transition zone separating normal marrow in the shaft from avascular marrow in the femoral head, visually identified by increased contrast enhancement.

Results

The surgical devascularization procedure inducing acute osteonecrosis of the right femoral head was successful in all five animals. Histomorphologic analysis of the harvested femora after sacrifice of the five animals 3 days ($n = 3$) and 7 days ($n = 2$) after surgery showed a total absence of fluorescent tetracycline in the affected femoral heads (Fig. 1). Absence of the fluorescent substance confirms lack of bone viability (Malizos KN, Quarles LD, Seaber AV, unpublished data).

Immediately after the devascularization procedure, conventional SE and STIR images did not show the abnormality in the avascular femoral head. SI measurements in the marrow cavities of the devascularized and intact femoral heads relative to muscle were not significantly different on T1-weighted images ($p = .28$), T2-weighted images ($p = .72$), or STIR images ($p = .5$) (Figs. 2 and 3). Similarly, no differentiation based on T2 relaxation time calculations was possible ($p = .731$) (Fig. 2).

Conversely, significant differences were present in the enhancement profiles of the marrow spaces in the two femoral heads. After injection of gadoteridol, enhancement of marrow in the normal and avascular femoral heads was markedly disparate in all animals. Figure 4 shows the mean percent enhancement for each of the three ROIs, ischemic right femoral head, normal left femoral head, and paraspinal mus-

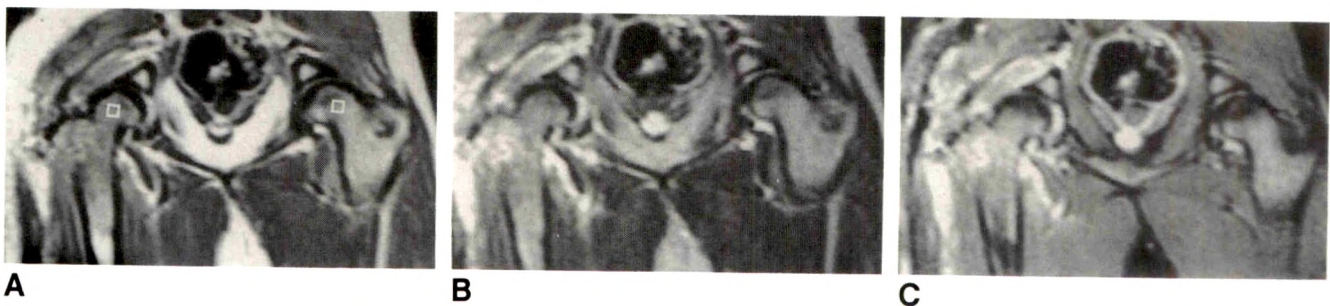


Fig. 3.—A–C, T1-weighted (500/20, A), T2-weighted (2000/80, B), and STIR (2000/40/160, C) MR images of both proximal femur marrow cavities were obtained within 3 hr after the devascularization procedure on a 1.5-T system. Relative to adjacent adductor muscles, no statistically significant differences in signal intensities are seen between marrow spaces in normal left and ischemic right femoral heads. Postsurgical changes manifested by increased signal on T2-weighted and STIR images are seen surrounding right hip.

cle. Single standard errors of the mean are indicated by bars. The dynamic SI profile of normal marrow was characterized by very rapid enhancement peaking on average at 36 sec, followed by a plateau phase with some washout. Enhance-

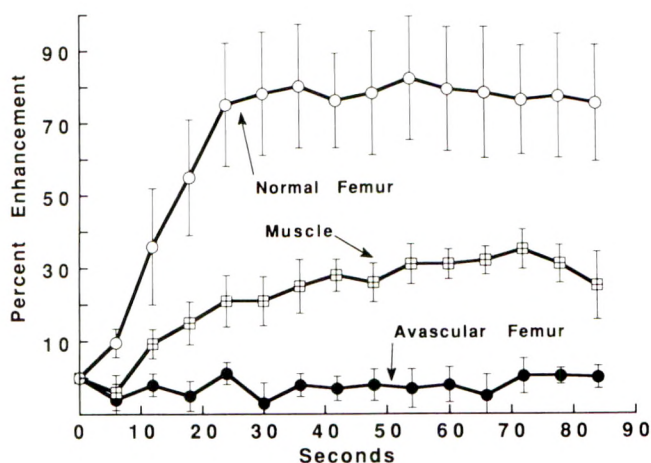


Fig. 4.—Mean percent enhancement plotted against time for three regions of interest: normal left femoral head, avascular right femoral head, and paraspinal muscle. Although enhancement of marrow space in normal femoral head is marked, no enhancement is seen for first 84 sec in avascular marrow cavity in right femoral head. Gradual enhancement is seen in paraspinal muscle. Single standard errors are indicated by bars.

ment of the paraspinal muscle was more gradual and peaked at 72 sec. SI measurements of the avascular marrow cavity showed a total lack of enhancement in the 90-sec imaging interval (Fig. 5). Although no significant enhancement was seen in any tissue in the first 6 sec, the maximal difference in SI between the two femoral marrow cavities was achieved within the subsequent 30 sec, when an SI increase of 83% was seen in the normal marrow cavity compared with 0% in the devascularized marrow cavity. Muscle tissue enhanced by about 30% in the same interval. For statistical analysis, areas under the enhancement curves were determined for the three ROIs in all five animals (Fig. 6). For right and left femora, these were significantly different ($p = .005$). Similarly, statistically significant differences were shown between the enhancement curves of each femoral head and muscle tissue ($p < .02$).

Analysis of the two studies done 7 days after the devascularization procedure revealed SI differences between the marrow cavities in the normal and avascular femoral heads on both SE and STIR images (Fig. 7). These were characterized by a 23% SI decrease on T1-weighted images, a 32% SI increase on the first echo of the T2-weighted images, a 78% SI increase on the second echo of the T2-weighted images, and a 103% SI increase on the STIR images. Absolute T2 relaxation times measured in the devascularized bone increased during the 1-week interval from 48 to 84 msec for the first dog and from 36 to 69 msec for the second dog.

Dynamic contrast-enhanced imaging 7 days after devas-

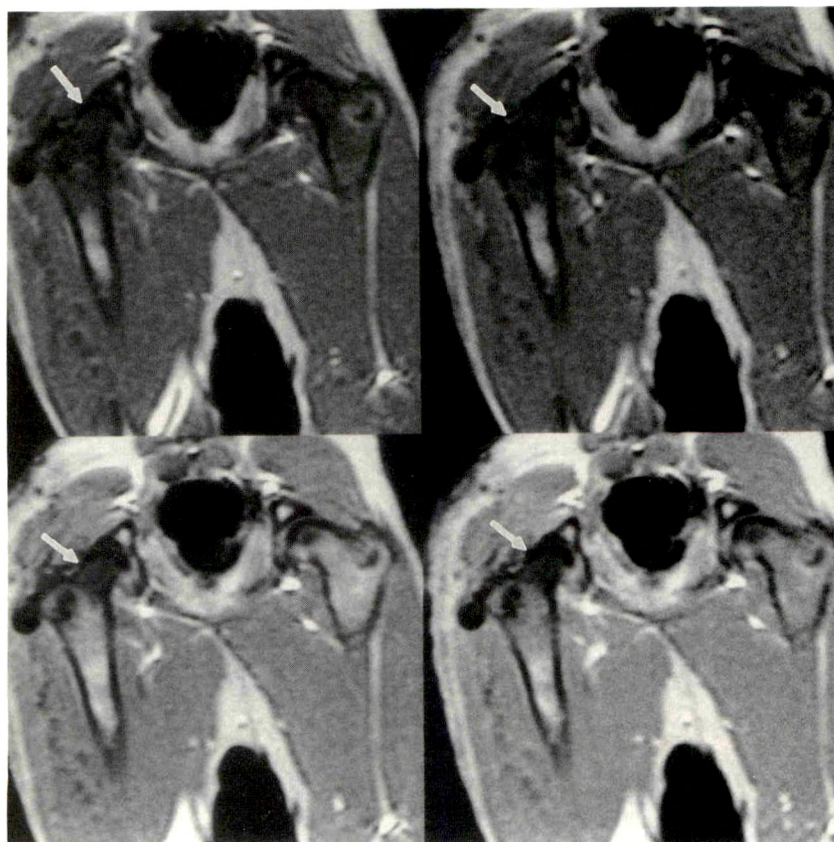


Fig. 5.—T1-weighted fast gradient-recalled-echo (28/5, 45° flip angle) MR images obtained within 3 hr of devascularization procedure at 0 sec (top left), 18 sec (top right), 36 sec (bottom left), and 72 sec (bottom right) after IV administration of 0.2 mmol/kg gadoteridol at a rate of 2 ml/sec. Marrow contained in normal femoral head and marrow in proximal bilateral femoral shafts enhance rapidly, peaking at 36 sec, but no enhancement occurs in ischemic right femoral head (arrows).

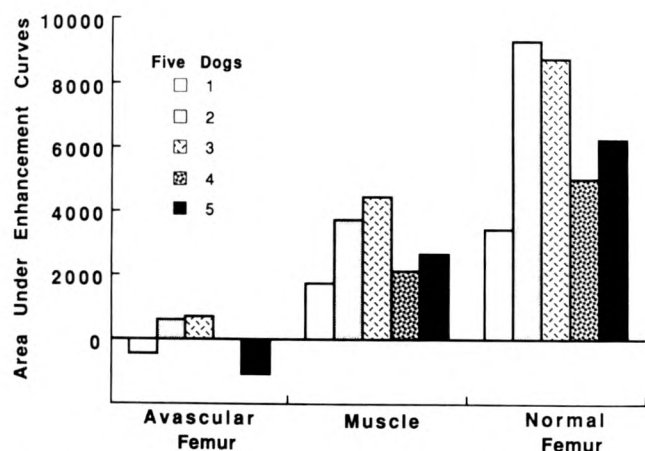


Fig. 6.—Areas under enhancement curves for three individual regions of interest (avascular right femoral head, paraspinal muscle, normal left femoral head) determined for all five dogs show statistically significant differences between avascular and normal femoral heads, as well as between muscle and avascular femoral heads and between muscle and normal femoral heads.

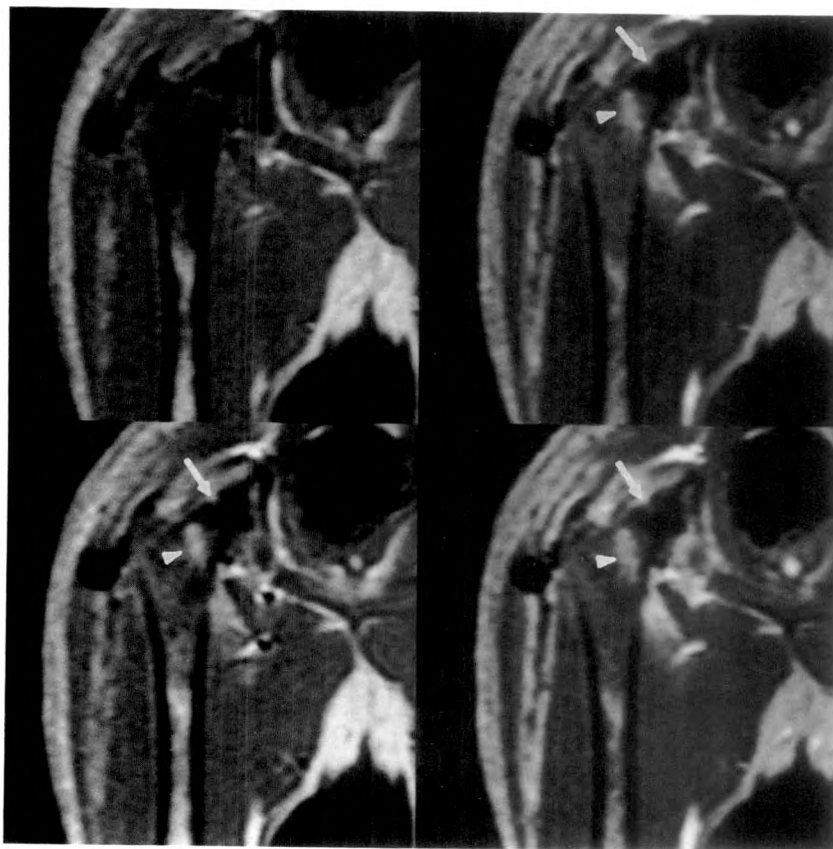


Fig. 7.—T2-weighted (2000/80) MR image obtained 7 days after devascularization procedure shows increased signal in marrow cavity of ischemic right femoral head. Again noted are postsurgical changes in surrounding soft tissues.

cularization showed three distinct zones of marrow enhancement in the avascular femur (Fig. 8). Similar to the immediate postoperative MR examination, enhancement was normal in the marrow of the femoral shaft, and enhancement was

virtually absent in the avascular marrow of the right femoral head. A third zone of enhancement was identified in the region of transition between normal and avascular marrow. In both dogs, this region was characterized by contrast enhancement

Fig. 8.—T1-weighted gradient-recalled-echo images (28/5, 45° flip angle) obtained 7 days after devascularization at 0 sec (top left), 18 sec (top right), 36 sec (bottom left), and 72 sec (bottom right) after IV administration of 0.2 mmol/kg of gadoteridol. Lack of enhancement in marrow of ischemic femoral head (arrows) is persistent. Marked enhancement is noted in marrow in normal femoral shaft. Very rapid enhancement without evidence of washout is identified in a junctional zone at interface of normal and avascular marrow (arrowheads).



in excess of 120% in the first 20 sec, as opposed to 70% in normal marrow in the same time span (Figs. 8 and 9).

Discussion

Ischemia of the femoral head occurs in a variety of clinical settings. These include traumatic disruption of the blood supply (femoral head dislocation and subcapital femoral neck fracture), hemoglobinopathies (sickle-cell disease), exogenous corticosteroid therapy and Cushing's disease, alcoholism, Gaucher's disease, dysbaric disorders, pregnancy, and irradiation [1]. Regardless of the cause, the natural history of osteonecrosis is the same: continued weight-bearing on devitalized bone eventually leads to collapse, joint deformity, degenerative change, and painful dysfunction [2]. The common first step in the development of osteonecrosis, however, is compromise of arterial blood flow to the affected bone [1]. In order to ensure the earliest possible diagnosis, it is desirable to image changes in the bones corresponding to this very first step.

A variety of osteonecrosis-inducing techniques have been used, including injection of powdered charcoal into the femora; multiple peripheral embolizations; systemic administration of steroids or alcohol; surgically invasive models; and more recently, the combination of femoral head dislocation, soft-tissue stripping, and deep freezing (Malizos KN, Quarles LD, Seaber AV, unpublished data). Of these, only the last method duplicates the salient characteristics of human disease by producing a uniform lesion in anatomic proximity to the articular surface of the femoral head and continuous with adjacent viable bone, which manifests normal loading during the healing process (Malizos KN, et al., presented at the Orthopaedic Research Society meeting, March 1991). It must be pointed out that this model simulates most closely the condition of traumatic arterial interruption. Because compromise of the arterial blood flow appears to be the underlying first step in the development of osteonecrosis [1], we believe

that this osteonecrosis-inducing technique may serve as a model for most forms of osteonecrosis, regardless of their underlying pathogenesis. It remains certainly possible, however, that the model used in this study only partially simulates the pathophysiology of some forms of osteonecrosis.

This study shows that techniques previously considered most sensitive (conventional SE and STIR) did not show the earliest changes associated with devascularization of the femoral head (Figs. 2 and 3). The ischemic changes were, however, apparent with rapid imaging after the dynamic injection of gadoteridol at a concentration of 0.2 mmol/kg of body weight (Figs. 4–6).

Gadoteridol is a nonionic paramagnetic metal ion chelate that has a low osmolality (630 mOsm/kg) in aqueous solutions. It has been suggested that the lower osmolality and greater in vitro chelate stability of this gadolinium-based MR contrast agent may improve safety and patients' tolerance [19, 20]. This compound has recently been found both safe and efficacious in imaging of CNS lesions at doses of 0.1, 0.2, and 0.3 mmol/kg of body weight [21, 22].

Similar to other paramagnetic contrast agents, gadoteridol is an extracellular agent that is rapidly cleared from the intravascular space. Fast dynamic imaging while contrast material is still intravascular is thus imperative. We used a T1-weighted gradient-echo sequence, permitting sequential 6-sec images in two locations. The data show that maximal contrast between the SI of marrow cavities in the normal and devascularized femoral heads is reached within 30 sec after the rapid dynamic injection of the contrast agent (Fig. 4).

The enhancement profiles of normal muscle and normal marrow in this study were slightly higher, more consistent, and peaked earlier than those reported to date. Reiser et al. [23] reported a 23.6% mean SI enhancement in muscle 4 min after dynamic IV administration of 0.1 mmol of gadopentetate dimeglumine per kilogram of body weight. The greater enhancement of up to 35% in our study largely reflects the increased concentration of paramagnetic contrast material (0.2 mmol/kg of body weight) as well as rapid bolus administration.

The time of peak enhancement of normal femoral marrow (28–33 sec) in our study was shorter and more consistent than that previously reported (46–299 sec) [24]. This most likely reflects the infusion at a higher rate (2 ml/sec) and the use of an automated injector. Automation of the injection process consistently delivered the same amount of contrast material in the same amount of time to the ROI.

Lack of contrast enhancement in the devascularized femoral head reflects the absence of perfusion. The interdependence of blood flow and contrast enhancement has most recently been demonstrated by Cova et al. [24]. In their study of five adult mongrel dogs that had undergone arterial embolization of one leg, the authors noted, after the administration of 0.2 mmol of gadopentetate dimeglumine per kilogram of body weight, significantly less enhancement in bone marrow and muscle in the ischemic leg compared with the normal (control) leg [24].

In contrast to the marked SI difference between normal and devascularized femoral heads after administration of gadoteridol, conventional T1- and T2-weighted SE and STIR images did not show any acute change in the devascularized

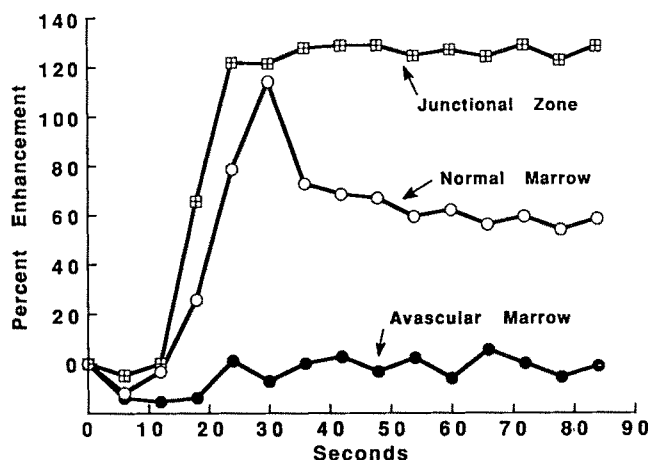


Fig. 9.—Percent enhancement plotted over time for marrow space in avascular femoral head, marrow in normal shaft, and a junctional zone identified at interface between normal and avascular marrow. Enhancement in junctional zone exceeds enhancement in normal marrow. Lack of enhancement persists in marrow of avascular femoral head 7 days after devascularization.

femoral head (Figs. 2 and 3). Imaging characteristics consistent with AVN were, however, present in two studies done 7 days after devascularization. These results concur with observations made by Brody et al. [12], who evaluated surgically devascularized distal femora of adult beagle dogs with T1-weighted sequences and a 0.35-T system. The authors reported areas of decreased SI on the T1-weighted images as early as 1 week after acute interruption of the vascular supply. These early MR changes were found to correspond to fat necrosis and an inflammatory infiltrate associated with fibroblastic repair [12]. It is likely that this inflammatory response caused the increase in T2 and STIR SIs observed in our study. Similar findings were reported by Lang et al. [3, 18], who inferred from repeated imaging of excised porcine femora in a 72-hr period that SI changes on conventional SE images require the presence of an intact and vigorous repair response within adjacent viable bone [18].

The dynamic gadoteridol-enhanced images obtained 7 days after the devascularization procedure show persistent lack of enhancement in the marrow cavity in the affected femoral head (Figs. 8 and 9). In both studies, however, an area of significantly increased contrast enhancement was seen at the interface of normal bone marrow and necrosis (Fig. 8). Relative contrast enhancement in that region (120%) was significantly higher than that of normal marrow (70%). Similar observations have been reported by Bloem et al. [25], who found mesenchymal repair tissue at the interface of normal bone with necrosis to enhance markedly. It has been suggested that this area of mesenchymal proliferation may in fact represent healing. This may be of particular interest in the surgically treated hip. On the basis of the findings in the two evaluated animals, however, we cannot exclude the possibility that the region of transition in the avascular marrow may be related directly to the freezing procedure used to induce AVN.

From our experimental model we conclude that dynamic MR imaging after the bolus injection of 0.2 mmol of gadoteridol per kilogram of body weight is significantly more sensitive in the detection of early acute AVN than are conventional SE and STIR imaging. Contrast enhancement in normal marrow was marked, peaking as early as 30 sec after bolus administration; virtually no enhancement was seen in the marrow cavity of the devascularized femoral head. This technique may thus be most valuable for examining patients at risk for AVN when symptoms are minor and complete infarction has yet to occur. Dynamic contrast-enhanced MR imaging 7 days after devascularization suggested the presence of repair tissues. The potential ability to differentiate between nonperfused, nonviable necrotic tissue and viable, perfused reparative tissue may aid in disease classification and in posttreatment evaluations.

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Book Review

Musculoskeletal Oncology. A Multidisciplinary Approach. Edited by Michael M. Lewis. Philadelphia: Saunders, 529 pp., 1992. \$95

The goal of this book is to provide an "integrated" approach to the topic of musculoskeletal oncology. Understandably, the difficulty of doing so is directly proportional to the number of coauthors. This book has 54 authors and 27 chapters. Ten chapters have only one author; the rest have as many as six each.

Chapters 1 and 2 are clearly the strongest of the book. The first provides an extremely practical approach to evaluating bone and soft-tissue tumors. The author reiterates Dr. Enneking's four primary questions that should be answered when plain radiographs are used to evaluate a musculoskeletal lesion: (1) Where is the lesion? (2) What is the lesion doing to the bone? (3) What is the bone doing to the lesion? (4) Is there any characteristic within the lesion to suggest a specific diagnosis?

Some of the statements made in this chapter are slightly controversial, but they are principles with which I agree wholeheartedly. For example, the author states: "The primary objections to performing a biopsy for every abnormality seen on an x-ray film are that many need no treatment and the biopsy makes observation of the lesion's natural history impossible." The author also strongly emphasizes the need for close cooperation between orthopedic surgeons, pathologists, and radiologists in evaluating bone or soft-tissue tumors: "The orthopedist requesting a special radiologic examination . . . or a biopsy interpretation . . . should tell the radiologist and the pathologist what specific information is needed." It is extremely refreshing to read comments of this nature from an expert oncologic orthopedic surgeon. In many respects, this merely seems like common sense. Why is it not intuitively obvious to all orthopedic surgeons?

Chapter 2 is devoted to the radiology and pathology of bone tumors. The most commonly encountered bone tumors are discussed briefly. The radiologic images are of excellent quality. It is frustrating, however, to be confronted with black-and-white (rather than color) photomicrographs. In addition, this chapter has a deficiency that is repeated in many other chapters: no mention of soft-tissue tumors. On a similar note, chapter 3 is nicely written and, as its title suggests, describes the principles of pediatric oncology. However, as this is supposed to be a book on musculoskeletal oncology, I would prefer a chapter more focused toward this topic.

Chapter 4 discusses the most common malignant solid tumors of childhood that can cause skeletal metastases. Unfortunately, the educational value is considerably diminished by the lack of radiologic and pathologic images. Chapter 8, "The Geriatric Patient," is interesting and short, but largely irrelevant to this textbook. It is not immediately clear why chapters 10, "Osseous Lesions of the Vertebral Axis and Tumors of the Cervical Spine," and 11, "Tumors of the Thoracolumbar Spine," were not combined. Throughout the book, many of the chapters are devoted to specific anatomic regions of the skeleton (e.g., bony thorax, pelvis, hand, shoulder girdle, proximal femur, knee, foot and ankle). For some reason, the elbow is largely overlooked. Chapter 22 discusses osteoporosis, osteomalacia, Paget's disease, and hyperparathyroidism. As the coverage of these topics is superficial, and they are not likely to be confused with primary bone tumors, this chapter could be deleted without adverse consequences.

This textbook is not encyclopedic, but it does provide an overview of musculoskeletal oncology. Although it has considerable redundancy, it also has many chapters that are focused almost entirely on bone tumors, to the exclusion of soft-tissue lesions. In addition, some of the images are oriented unconventionally. For instance, an angiogram (and the accompanying photograph of the resected specimen) of a patient with osteosarcoma of the distal femur is oriented horizontally rather than vertically, as it always would be on the view box. Careful proofing should prevent this type of mistake. Understandably, this lack of attention to detail detracts from the quality of the book. This book will be a useful reference for physicians who are interested in musculoskeletal tumors, but it is unlikely to appeal to residents, because of its broad, multidisciplinary approach to a relatively uncommon topic.

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Case Report

CT Findings in a Case of Exuberant Cervical Fibrosclerosis

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Idiopathic fibrosing syndromes comprise a group of disorders that have similar histologic appearances and affect different body regions. These syndromes include retroperitoneal, pulmonary, and mediastinal fibrosis; sclerosing cholangitis; Riedel's thyroiditis; orbital fibrosis; and sclerosing cervicitis. Cervical fibrosclerosis has been reported in the literature only infrequently [1-5]. This disorder has been described by using different terms such as sclerosing cervicitis, tumefactive fibroinflammatory lesion of the head and neck, and idiopathic fibrosis of the lateral compartment of the neck [1-3]. Despite its benign histologic findings, clinically and radiologically the disease may appear to be malignant. To our knowledge, this is the first case in the radiologic literature to describe the CT findings of this rare disorder.

Case Report

A 48-year-old man had a 1-year history of progressive and painless bilateral swelling in the neck. He had no constitutional symptoms. Open biopsy of the neck lesion showed fibrosis with chronic inflammation. Immunohistochemical analysis revealed a polyclonal T-cell receptor gene rearrangement. The implication of this finding is not clear. No malignant cells were identified, and the findings were thought to be compatible with cervical fibrosclerosis. The patient was discharged and treated with a 6-week tapered prednisone regimen.

The patient returned 4 years later, having had worsening neck swelling and difficulty breathing during sleep for 6 months. On physical examination, the neck was markedly and symmetrically enlarged from the submandibular regions bilaterally down to the supraclavicular fossae. The neck was hard, nontender, and diffusely swollen. We found no erythema or induration of the overlying skin, which was

taut. Clinically, the hypopharynx was narrowed, and its mucous membranes were intact.

CT examination showed an infiltrating and enhancing process diffusely involving the superficial and deep tissues of the neck, extending from the level of the zygoma down to the clavicles bilaterally (Fig. 1A). Both the anterior and posterior triangles of the neck were extensively involved, with encasement of muscles and invasion of fat planes (Fig. 1B). The hypopharynx was narrowed because of extrinsic compression.

Another biopsy was done on the mass, and again fibrosis and chronic inflammatory cells were found. No malignant tissue was identified. The patient was discharged on tamoxifen therapy and is now stable.

Discussion

Although sclerosing fibrous overgrowths may affect widely distant organ systems, their histologic and clinical manifestations often are similar. Involvement of the head and neck by fibrosing disorders has been reported only infrequently in the radiology literature [1-7]. Initially, the term sclerosing cervicitis was coined by Rice et al. [3] in 1975 to describe this entity as the cervical homologue of retroperitoneal and mediastinal fibrosis. A distinct form of idiopathic fibrosis of the lateral compartments of the neck was later described by Esdaile et al. [6]. That form of the disease, now recognized as cervical fibrosclerosis, is histologically characterized by dense fibrous tissues infiltrated by lymphocytes, plasma cells, macrophages, and scattered eosinophils and neutrophils [5]. No malignant cells should be present. The presence of T-cell gene rearrangement in our case is unclear and raises the possibility that this disorder may be related to the T-cell

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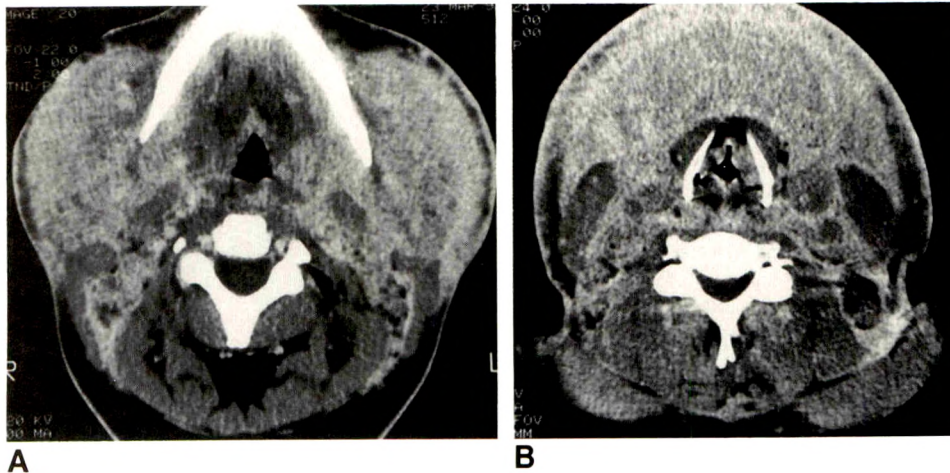


Fig. 1.—A, Axial contrast-enhanced CT scan at level of mandible shows extensive enhancing abnormal soft tissue diffusely infiltrating both cheeks, encasing sternocleidomastoid muscles, and extending into posterior triangles. Medially, infiltration has occurred at base of tongue and near palatine tonsils. Mass insinuates itself in prevertebral space (posterior to left longus colli muscle).

B, Contrast-enhanced CT scan at level of thyroid cartilage shows extremely large mass infiltrating muscles and structures in carotid-jugular sheaths. Carotid arteries and jugular veins are not clearly seen, possibly because of significant extrinsic compression by mass. Clearly seen is abnormal enhancing tissue in prevertebral space. Airway is narrowed because of extrinsic compression. Clinically, mucosal surfaces of airway were normal.

malignant neoplasms. Although the cause of this disease remains unclear, hypersensitivity reactions, autoimmune reactions, genetics, neoplasia, and drugs have all been implicated as causal factors [5]. Treatment with steroids, chemotherapeutic agents, hormonal therapy, radiation, or surgery has produced mixed and disappointing results [7].

In our patient, the involvement was confined to the neck. Symptoms included primarily painless swelling of the neck with associated sleep apnea due to extrinsic compression of the airway. Signs and symptoms such as facial or neck pain, headache, dysphagia, hoarseness, trismus, epistaxis, proptosis, and nasal obstruction also have been reported [4].

The CT appearance of this process is striking, and to our knowledge it has not been reported in the radiologic literature. In our case, the enhancing process diffusely infiltrated the soft tissues of the neck, but did not originate from any one structure. The mass encased fat, cervical musculature, salivary glands, and the carotid/jugular sheaths. CT clearly showed both the extent of this rare lesion and the degree of airway compression. From the imaging standpoint, the differential diagnosis should include lymphoma and aggressive fibromatosis. The latter is a well-differentiated desmoid proc-

ess, similar to a diffuse fibrosarcoma, but with a benign histologic appearance [7]. CT shows aggressive fibromatosis as a diffuse infiltrating fibrous process occurring near musculoaponeurotic junctions [7]. Because of the similar appearances of these lesions, the diagnosis relies on histologic examination.

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Acute Appendicitis in Children: Value of Sonography in Detecting Perforation

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OBJECTIVE. We determined the sonographic features of perforating appendicitis in children in order to determine the best criteria for establishing the diagnosis.

MATERIALS AND METHODS. Sonograms of the right lower quadrants of 71 children with proved appendicitis were reviewed to determine the value of sonography in distinguishing between nonperforating and perforating appendicitis. The sonographic signs evaluated included the presence or absence of an appendix, an echogenic submucosal layer, increased periappendiceal echogenicity, free or loculated periappendiceal or pelvic fluid collections, and appendicoliths. The sonographic findings were correlated with the surgical and pathologic findings.

RESULTS. Forty-five patients had nonperforating appendicitis, and 26 had perforating appendicitis. A sonographically visible appendix was present in all patients with nonperforating appendicitis and in 10 (38%) of 26 patients with perforation. An echogenic submucosa was noted in 27 (60%) of 45 patients with uncomplicated appendicitis but in only three (30%) of 10 patients with a visible appendix and perforating appendicitis ($p < .05$). In 19 of 26 patients with perforating appendicitis, sonography showed loculated periappendiceal or pelvic fluid collections; no patient with nonperforating appendicitis had a loculated fluid collection ($p < .05$). No statistically significant association was found between the presence or absence of perforation and free pelvic fluid, prominent periappendiceal fat, or an appendicolith.

CONCLUSION. Our results indicate that sonography can be helpful in the diagnosis of perforating appendicitis. The best predictors of perforation are absence of the echogenic submucosal layer and the presence of a loculated fluid collection.

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Graded-compression sonography of the right lower quadrant using a high-resolution, linear-array transducer has been shown to be a useful technique for diagnosing appendicitis, with a sensitivity between 80% and 95% [1-8]. Recently, attempts have been made to differentiate between nonperforating and perforating appendicitis by using sonography [6, 9]. Puylaert et al. [6] reported a sensitivity of 29% for sonography in diagnosing perforating appendicitis. A more recent investigation by Borushok et al. [9] showed that no single sonographic finding was sensitive in diagnosing perforation, but that when a combination of findings was used, the sensitivity of sonography for diagnosing appendiceal perforation increased to 86%. Both these studies evaluated mainly adult patients. In a small series, Vignault et al. [8] described one sonographic finding (diffuse hypoechogenicity) that appeared to be highly suggestive of perforation in children. To better determine the value of sonography in distinguishing between nonperforating and perforating appendicitis in children, we reviewed the sonographic findings in 71 children with appendicitis, 26 of whom had appendiceal perforation.

Materials and Methods

We retrospectively reviewed the sonograms of 79 children with surgically proved appen-

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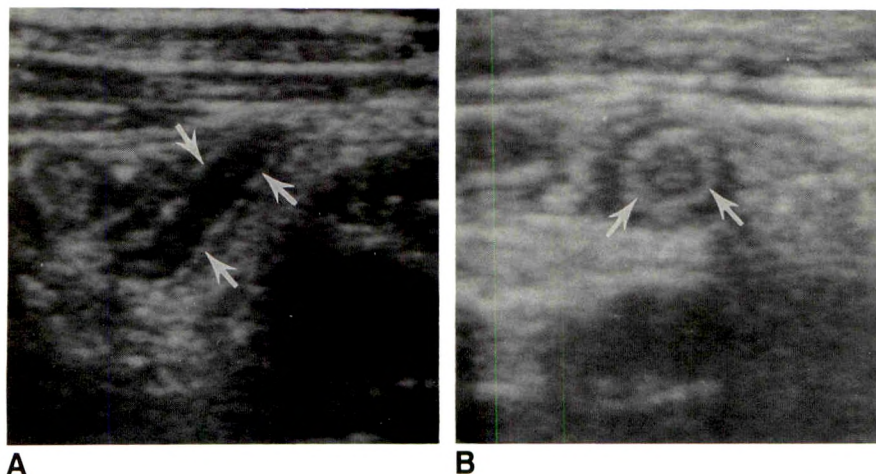


Fig. 1.—Nonperforating appendicitis.

A, Longitudinal sonogram shows a noncompressible, tubular appendix with an echogenic submucosal layer (arrows) and a hypoechoic center.

B, Transverse sonogram in another patient shows a target appearance with a hypoechoic lumen containing scattered debris, a more echogenic submucosa (arrows), and hypoechoic wall.

ditis who were examined between January 1988 and December 1991. All sonograms were obtained with a 5-MHz linear-array transducer by using the graded-compression technique described by Puylaert [5]. Images of the right lower quadrant were obtained in longitudinal and transverse planes. Surgery was performed within 36 hr of the sonographic examination in all but two patients.

Seventy-one patients had abnormal sonographic findings and were shown to have appendicitis at surgery. There were 43 boys and 28 girls, ranging from 19 months to 18 years old (mean age, 11 years). Of the 26 patients with appendiceal perforations, 15 were boys and 11 were girls, ranging in age from 19 months to 17 years (mean, 10 years). In eight patients, the results of sonography were falsely negative, and these patients were excluded from the study. None of these patients had perforating appendicitis. Obesity accounted for the difficulty in identifying appendicitis by sonography in one of the eight patients. Adequate graded compression could not be achieved because of severe pain in two patients. The other false-negative studies had no obvious explanation.

The sonograms were reviewed blindly without knowledge of the surgical or pathologic findings. Images were evaluated with specific attention to the presence or absence of an appendix, an echogenic submucosal layer, increased periappendiceal echogenicity, free or loculated periappendiceal or other pelvic fluid collections, and appendicoliths.

Surgical and pathologic reports of each patient were retrospectively reviewed for the presence or absence of perforation, abscess, and appendicoliths, and those results were compared with the sonographic findings. Statistical analysis with a Fisher exact two-tailed

test was done to evaluate the usefulness of individual sonographic features in diagnosing perforation.

Results

The sonographic findings are summarized in Table 1. Forty-five patients had nonperforating appendicitis, and 26 had perforating appendicitis. A visible appendix with a diameter of greater than 6 mm was seen in all 45 patients with nonperforating appendicitis and in 10 (38%) of 26 patients with perforation. An echogenic submucosa was visualized in 27 (60%) of 45 patients with uncomplicated appendicitis (Fig. 1) and in three of 10 patients with perforating appendicitis and a sonographically recognizable appendix ($p < .05$). The presence of the echogenic submucosa produced a target sign on transverse sonograms, characterized by a hypoechoic center representing intraluminal fluid or pus, a hyperechoic submucosal layer, and a hypoechoic muscular rim. A diffusely hypoechoic appendix with or without scattered internal echoes but without an echogenic submucosa was seen in 18 of 45 patients with nonperforating appendicitis (Fig. 2) and in seven of 10 patients with perforating appendicitis and a sonographically identifiable appendix.

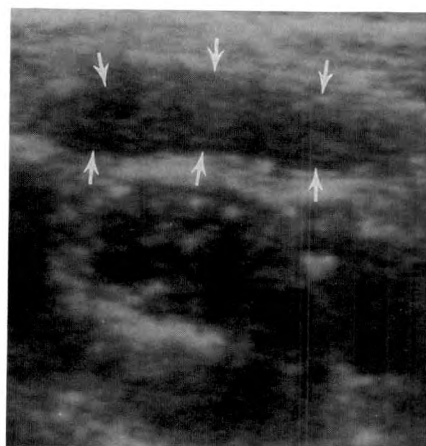
Loculated periappendiceal or pelvic fluid collections were seen in 19 (73%) of 26 patients with perforation (Figs. 3 and 4) and in none of the 45 patients without perforation ($p < .05$). Free fluid in the right lower quadrant or pelvis was seen in 14 (31%) of 45 patients with nonperforating appendicitis and in 13 (50%) of 26 patients with perforation. Prominent periappendiceal echogenicity (Fig. 5) and appendicoliths were noted in six (13%) and eight (18%) patients without perforation, respectively. In patients with perforation, prominent periappendiceal echogenicity and appendicoliths were noted in eight patients (31%) each. These differences were not statistically significant.

On gross examination, the nonperforated appendix usually was characterized by congestion and serosal hyperemia. After perforation, the appendix was distorted and covered by a purulent exudate. Microscopically, the changes ranged from minimal inflammation of the mucosa and submucosa to necrosis and destruction of these layers and the wall. Appendi-

TABLE 1: Sonographic Findings in Perforating and Nonperforating Appendicitis

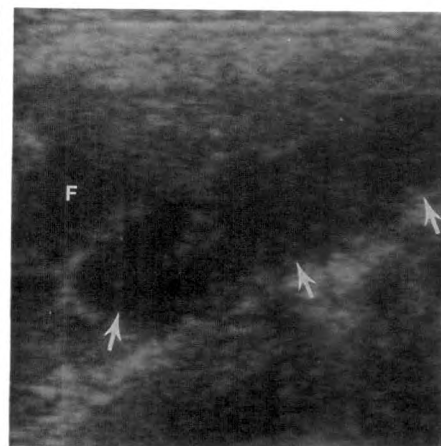
Sonographic Findings	No. (%) of Patients	
	Nonperforating (n = 45)	Perforating (n = 26)
Visible appendix	45 (100)	10 (38)
Echogenic submucosa	27 (60)	3 (30)
Hypoechoic appendix	18 (40)	7 (70)
Loculated pericecal fluid	0 (0)	19 (73)
Free intraperitoneal fluid	14 (31)	13 (50)
Increased periappendiceal echogenicity	6 (13)	8 (31)
Appendicolith	8 (18)	8 (31)

Fig. 2.—Nonperforating appendicitis. Longitudinal sonogram shows a dilated appendix (arrows) with a hypoechoic lumen. Note loss of echogenic submucosa. During surgery, distal tip was found to be grossly distended and inflamed without evidence of perforation.



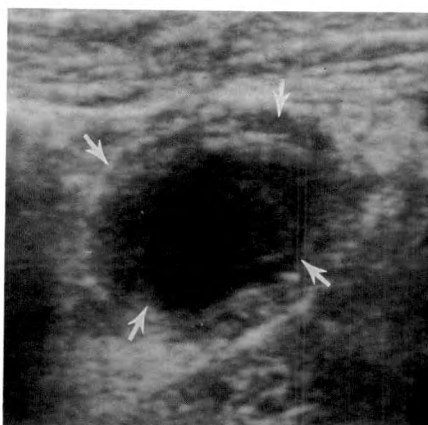
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Fig. 3.—Perforated appendix with periappendiceal fluid. Longitudinal sonogram shows an irregular, poorly defined appendix (arrows). A noncompressible fluid collection (F) is noted adjacent to appendiceal tip. Perforated appendix with a periappendiceal abscess was found during surgery.



3

Fig. 4.—Perforating appendicitis. Longitudinal sonogram shows a rounded, noncompressible fluid collection (arrows) in right lower quadrant. No appendix was identifiable at sonography. Pericecal abscess was found during surgery.



4

Fig. 5.—Perforated appendix. Longitudinal sonogram shows a diffusely hypoechoic appendix, loss of echogenic submucosa, and echogenic periappendiceal fat (arrows). Acute appendicitis with a perforated tip and periappendiceal phlegmon were noted during surgery. Echogenic focus (arrowhead) in appendiceal tip represented an appendicolith.



5

coliths were found in eight patients without perforation and in 15 patients with perforation.

Discussion

High-resolution sonography with graded compression has proved to be a reliable technique for establishing the diagnosis of appendicitis in adults and children. However, the usefulness of sonography in the diagnosis of perforating appendicitis is more controversial, with its relatively low sensitivity of 29% reported in a series by Puylaert et al. [6] and its relatively high sensitivity of 86% reported by Borushok et al. [9].

Appendiceal perforation was seen in 13–30% of children, with rates as high as 90% in infants [10, 11]. The 38% frequency of perforation in this series is, therefore, not unexpected. Identification of appendiceal perforation is important because it can alter clinical management. Prompt appendectomy is the treatment of choice in patients with nonperforating appendicitis or small perforations. However, in patients with periappendiceal phlegmon (i.e., an indurated soft-tissue mass without drainable pus) or relatively small periappendiceal abscesses, conservative management with antibiotic therapy followed by appendectomy at a later time through a cleaner

surgical field may be desirable. In patients with large or well-defined appendiceal abscesses, percutaneous catheter drainage may be preferred to early surgery [12, 13].

Our study confirms the value of sonography in identifying abnormalities in patients with perforation. In our series, an echogenic mucosa was visualized in 60% of patients with uncomplicated appendicitis and in 30% of patients with a visible appendix and perforating appendicitis. Conversely, loss of the echogenic layer of the submucosa was seen in 40% of patients with nonperforating appendicitis and 70% of patients with perforating appendicitis and a visible appendix. It has been postulated that the loss of the sonographic echogenic submucosa reflects extensive submucosal necrosis that predisposes to perforation [9]. On the basis of an observed absence of echogenic submucosa, we found the sensitivity of sonography in perforated appendicitis to be similar to that found by Vignault et al. [8], who reported loss of the submucosa in 25% of children with nonperforating appendicitis and in 75% of children with perforating appendicitis. Our study also confirms the data of Borushok et al. [9], who reported a 60% sensitivity of sonography in the diagnosis of perforating appendicitis in patients with a visible appendix without an echogenic lining.

Loculated periappendiceal or pelvic fluid was seen in 73% of our patients with perforation and was 100% specific for the diagnosis. The loculated fluid collections varied in size from 2 to 12 cm in diameter, were often round and complex, and had mass effect on adjacent structures. Borushok et al. [9] reported that the finding of loculated pericecal fluid had a sensitivity of 41% and a specificity of 100% for the diagnosis of perforating appendicitis in their primarily adult series. The increased frequency of loculated fluid in our patients compared with that found in the study by Borushok et al. may be attributable to the younger age and the higher perforation rate in our study group.

Prominent periappendiceal echogenicity occurred in 13% of patients without appendiceal perforation and in 31% of patients with appendiceal perforation in our series. Borushok et al. [9] reported prominent pericecal fat in 50% of their patients with perforation and suggested that it represented inflamed mesenteric or omental fat. The low frequency of periappendiceal echogenicity in our study may reflect the paucity of perivisceral fat in younger children.

The presence of free fluid in the right lower quadrant or cul-de-sac and appendicoliths were not specific for perforation and were seen in children both with and without perforation in our series. Free fluid was seen in 50% of our patients with perforation and in 31% of patients without perforation. Appendicoliths were noted in 18% of patients with uncomplicated appendicitis and in 31% of patients with perforating appendicitis. The differences were not statistically significant. Borushok et al. [9] also found no statistically significant correlation between the presence of free fluid or appendicoliths and appendiceal perforation. We found appendicoliths in children with perforating appendicitis more often on pathologic specimens than on sonograms.

In our experience, the appendix is visible on sonograms in 70% of children with appendicitis. The absence of the echogenic submucosal layer and the presence of a loculated fluid collection are the most conclusive sonographic findings of perforating appendicitis.

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Congenital Subglottic Hemangioma: Frequency of Symmetric Subglottic Narrowing on Frontal Radiographs of the Neck

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David Levitsky¹

OBJECTIVE. This study was undertaken to determine how often symmetric subglottic airway narrowing is present in cases of infantile subglottic stenosis and to determine if the radiographic finding has any association with the anatomic location of the hemangioma.

MATERIALS AND METHODS. All cases ($n = 12$) of endoscopically proved subglottic hemangioma from 1976 to 1991 were collected from the records at Children's Hospital of Michigan. In 10 cases, high-kilovoltage magnification studies or frontal radiographs of the neck were available for review by two observers who classified the subglottic narrowing as either symmetric or asymmetric. The radiographic findings in these 10 cases were then compared with the location and extent of the lesion as described endoscopically.

RESULTS. In 50% of cases ($n = 5$), narrowing of the subglottic airway was symmetric. In four of these the hemangioma was either situated on the posterior wall or was circumferential, and in the remaining one an associated marked fibrotic reaction to a lateral wall lesion was present. All other lesions were on the lateral wall, and asymmetric subglottic airway narrowing was consistently shown on radiographs.

CONCLUSION. Our results show that subglottic hemangioma often manifests as a symmetric subglottic airway narrowing and that the anatomic location of the hemangioma appears to be associated with the appearance on radiographs.

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Subglottic hemangioma is a cause of severe, even life-threatening respiratory obstruction in infants [1-3]. Although definitive diagnosis is made by endoscopic examination or biopsy or both [1-3], the diagnosis is suggested when typical asymmetric subglottic narrowing is seen on frontal radiographs of the neck. Whereas congenital subglottic stenosis, another cause of stridor in neonates, characteristically produces symmetric subglottic narrowing, it has been suggested that subglottic hemangioma consistently produces a distinctive asymmetric narrowing on the frontal radiograph [4].

To determine how often the "diagnostic" finding of asymmetric subglottic narrowing is present in cases of infantile subglottic hemangioma, we reviewed the spectrum of plain film findings in 10 cases of endoscopically proved subglottic hemangioma collected at Children's Hospital of Michigan from 1976 to 1991.

Materials and Methods

Twelve cases of confirmed infantile subglottic hemangioma were collected by reviewing the records at Children's Hospital of Michigan from 1976 to 1991. In all cases, the diagnosis of subglottic hemangioma was made by direct endoscopic examination with confirming biopsy in some instances. Of the 12 cases, one neonate experienced respiratory distress at birth and was immediately intubated; thus, no radiographic studies were performed before instrumentation and no views of the neck were obtained before the diagnosis was made. One other patient was excluded from this study because no radiographs were available for review.

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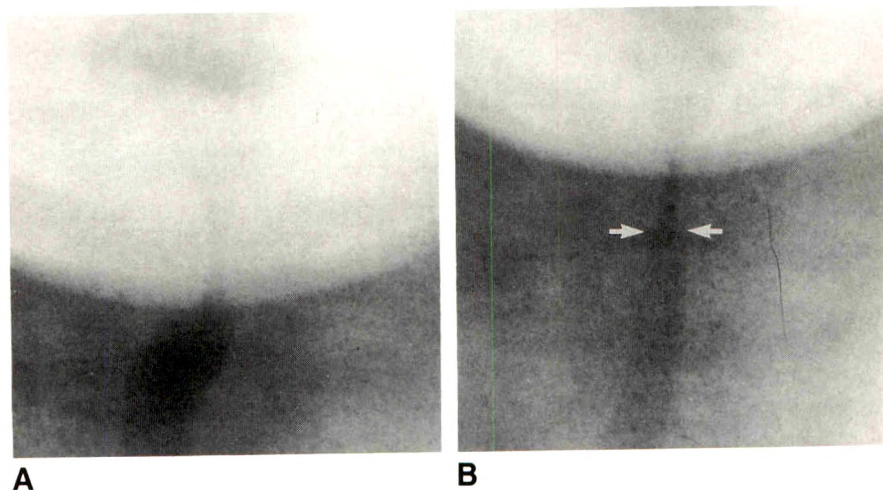


Fig. 1.—Effect of tracheal buckling (magnification, high-kilovoltage frontal film with Thoreaus filter obtained at fluoroscopy).

A, Radiograph gives misleading impression of asymmetric narrowing of subglottic airway during expiration with buckling of trachea.

B, Radiograph taken during inspiration with trachea in a neutral position shows that subglottic airway is symmetrically narrowed (arrows).

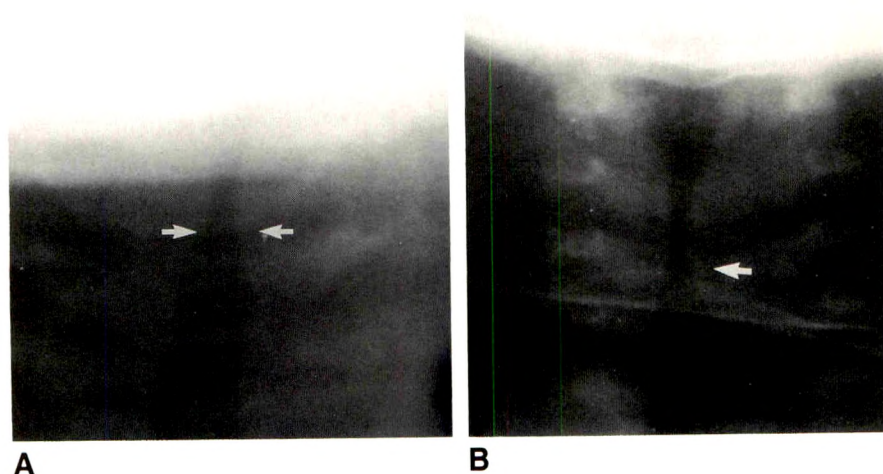


Fig. 2.—Different patterns of subglottic narrowing (magnification, high-kilovoltage frontal film with Thoreaus filter obtained at fluoroscopy).

A, Radiograph displays symmetric narrowing (arrows) of subglottic airway in a case of a hemangioma that was endoscopically shown to circumferentially involve mucosa from subglottis to carina.

B, Radiograph shows asymmetric narrowing of airway in a patient with a subglottic hemangioma (arrow) in left lateral wall.

Of the remaining 10 patients, nine had high-kilovoltage magnification static or fluoroscopic airway studies consisting of anteroposterior and lateral images taken in inspiration and expiration. In the final case, changes in the subglottic airway were evident on the frontal chest radiograph.

The images were reviewed by two observers who were aware of the diagnosis but not of the anatomic location of the hemangioma. The subglottic airway in each case was classified as either symmetrically or asymmetrically narrowed. In quiet breathing, if both lateral walls of the subglottic airway were convex and medially positioned, the narrowing was classified as symmetric; if only one wall was convex and medially positioned, the airway was considered asymmetrically narrowed. The findings on the radiographs were then compared with the location and extent of the lesion found on endoscopic examination.

Results

In 50% of cases ($n = 5$) narrowing of the subglottic airway was symmetric. In four of these, the hemangioma was either situated on the posterior wall or was circumferential, and the remaining one had an associated marked fibrotic reaction to a lateral wall lesion. All other lesions were on the lateral wall,

and asymmetric subglottic airway narrowing was consistently shown on radiographs.

Discussion

Although subglottic hemangioma can occur later in childhood, the neonate characteristically has inspiratory or biphasic stridor within a few weeks after birth [5]. Girls are most commonly affected, and cutaneous hemangiomas are present in about half the total number of cases [6–9]. Gradual involution of the hemangioma may occur after 12–18 months of age, but because the child's airway is often seriously compromised by the lesion, early diagnosis and surgical intervention is usually necessary [9].

It has been suggested that subglottic hemangioma consistently produces asymmetric narrowing of the subglottic airway on radiographic examination. However, in half our cases we found symmetric narrowing. It is important to assess the subglottic area on the images taken during inspiration because during expiration very marked tracheal buckling often occurs, and this can produce a misleading impression of asymmetric subglottic narrowing (Fig. 1). On the whole, the lateral radiographs in this group of patients did not prove useful in assessing the subglottic portion of the airway.

The location seen on the radiographs correlated well with that seen endoscopically. Whereas lesions located on the lateral wall consistently produced asymmetric narrowing, circumferential lesions, those on the posterior wall, and those associated with marked fibrotic reaction typically exhibited symmetric narrowing of the subglottic airway (Fig. 2).

It has been well documented that subglottic hemangioma is not the only lesion to produce asymmetric subglottic narrowing, and that, although uncommon in the neonate and young infant, other abnormalities such as cysts, granulomas, and papillomas can produce a similar asymmetrically narrowed subglottic airway [10].

Our results show that subglottic hemangioma can manifest as a symmetric narrowing that mimics congenital subglottic stenosis or, although unlikely in this age group, viral laryngotracheobronchitis. These findings should alert the radiologist to the possibility that a subglottic hemangioma could be the underlying problem in a neonate or young infant with stridor and a symmetrically narrowed subglottic area.

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Book Review

Practical Pediatric Imaging. Diagnostic Radiology of Infants and Children, 2nd ed. Edited by Donald R. Kirks. Boston: Little, Brown, 1099 pp., 1991. \$150

This is a valuable textbook that should be found on the shelves of all physicians interested in the care of children. For both radiologists in training and radiologists who have been in practice for many years, enough information is nicely presented to afford easy learning and sophisticated knowledge. For pediatricians, the same reasoning applies, but additional insight into what should be considered a reasonable differential diagnosis in any one circumstance and how to order the appropriate study makes the book appealing.

The text is divided into eight major chapters and five appendixes. Each chapter is written by at least one recognized expert in the area addressed. The information presented is authoritative, although it is occasionally weighted and expansive in sections that reflect the authors' unique areas of interest or bias. Nevertheless, almost all areas considered in the differential diagnoses receive at least some attention. The introduction in each chapter is an outline of the chapter's content. The outline is similar in each chapter, therefore guaranteeing logical presentations, easy access to the material, consistency, and comprehension. Variations in writing style are evident, but all authors are clear and deliberate, indicating an orchestration of material guided toward teaching as well as referencing.

The book has some problems specific to radiology texts. These include striking a balance between the amount of text devoted to topical scientific data in the area of interest (specifically pediatrics in this text) and the type and quantity of images for illustrating that material. In this book, the text outweighs the images in terms of amount and quality. This establishes the usefulness of the book for pediatricians but does not lessen its value to radiologists, who must understand the clinical picture the images reveal. The quality of some of the images and those selected for presentation is of some concern. Part of the problem here is difficulty in selecting which study to present and justifying the cost of publishing large numbers of "pictures," each of which varies in quality in its initial form. One or two

pictures for each differential diagnosis mentioned would be prohibitively expensive but gratifying to radiologists who want to see everything.

Almost everything that should be considered as a differential diagnosis is mentioned in numerous, extremely well organized comprehensive charts and lists. These provide the reader reminders of what else should be entertained in circumstances in which differential diagnoses must be considered. The lists mentioned are more complete than the references, which vary in quantity and specificity. References are neatly divided, however, into topics of interest. The appendixes include advice on preparation of the patient, appropriate radiographic projections, amounts of radiation doses generally absorbed in different studies, technique guidelines, and recommendations for contrast medium.

Although some of these advisements and data might be useful to most readers, the need for much of this information is limited. This statement might also apply to the technique portion of each chapter, which is not a complete technique "cookbook." It might be better to emphasize the difference required in using various techniques in children rather than in adults. Some interesting facts of this nature do appear in some chapters or are apparent or implied.

This book is a successful effort, and it does achieve goals established by the accepted standard textbooks in many areas of medicine. Criticism of any book can be made by anyone because of superficial coverage of one or two areas of specific interest not detailed. Although that is the case with this book as well, I strongly recommend it for its major strengths, for use in development and teaching, and as a reference.

William L. Schey
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Pictorial Essay

Atresia of the Colon in Neonates: Radiographic Findings

William D. Winters,¹ Edward Weinberger,¹ and Edwin I. Hatch²

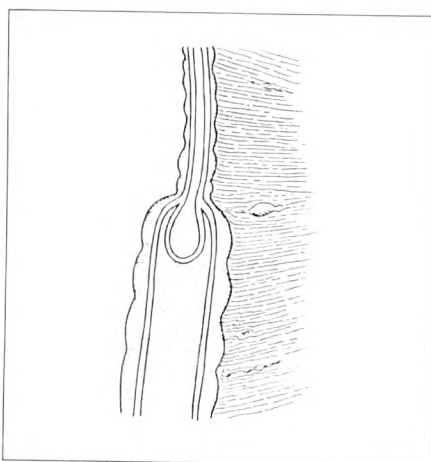
This essay illustrates the spectrum of plain film and contrast enema findings in patients with atresia of the colon. Typical examples of atresia of the proximal and distal colon, an intraluminal membrane, and multiple intestinal atresias are shown.

Atresia of the colon is a rare cause of intestinal obstruction in neonates; it accounts for less than 10% of all intestinal atresias. Because it is rarely seen even at a children's hospital, clinicians and radiologists often do not consider it in the differential diagnosis of intestinal obstruction in a neonate. Additionally, the onset of symptoms may be delayed until the second day or later after birth, increasing the risk of perfora-

tion, acid-base disturbances, and sepsis. The clinical manifestations are typical of those of distal intestinal obstruction and include vomiting, abdominal distension, and failure to pass meconium.

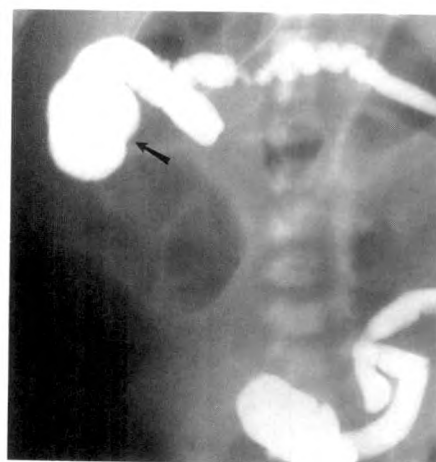
Bland-Sutton [1] described three types of colonic atresia. In type I, an obstructing intraluminal membrane is present, which may show the pathognomonic "wind sock" sign on contrast enema. In types II and III, the proximal and distal ends of the affected area are completely separate or connected by a cordlike remnant of bowel, with abrupt termination of the opacified colon on contrast enema. Louw [2] was able to produce all three in dogs by ligating mesenteric arteries

Fig. 1.—Type I atresia. An obstructing intraluminal membrane separates dilated proximal colon from small-diameter colon distally. Ballooning of membrane into dilated proximal colon during contrast enema produces "wind sock" sign. (Modified from Peck et al. [3].)



1

Fig. 2.—Type I atresia of ascending colon. Barium enema shows typical "wind sock" sign seen with type I atresia as intraluminal membrane balloons into dilated ascending colon (arrow).



2

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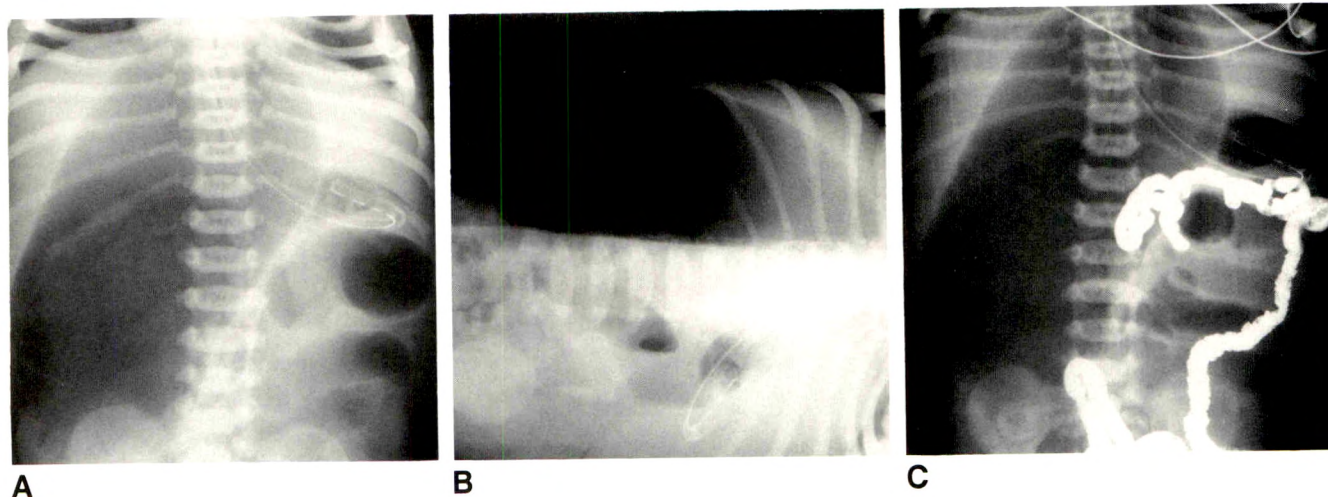


Fig. 3.—Atresia of ascending colon.

A and B, Radiographs of abdomen with patient supine (A) and in left lateral decubitus position (B) show markedly dilated ascending colon. Note prominent gas/fluid level on decubitus view (B).

C, Water-soluble contrast enema shows small-diameter transverse and descending colon. Column of contrast material terminates adjacent to distended ascending colon. Distension and necrosis of ascending colon and terminal ileum were found at surgery.

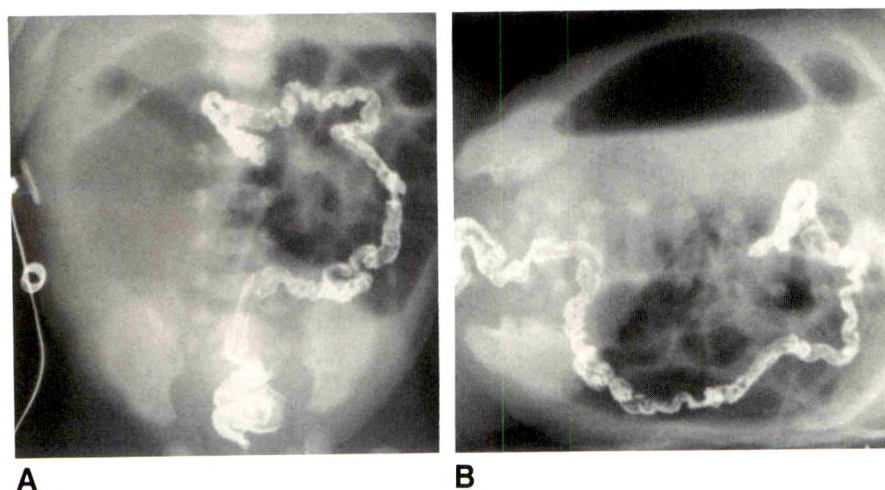


Fig. 4.—Atresia of ascending colon.

A and B, Radiographs with patient supine (A) and in left lateral decubitus position (B) obtained after water-soluble contrast enema show dilated ascending colon. Note prominent gas/fluid level on decubitus view (B). Opacified colon is small in caliber, and column of contrast material terminates adjacent to dilated loop of ascending colon.

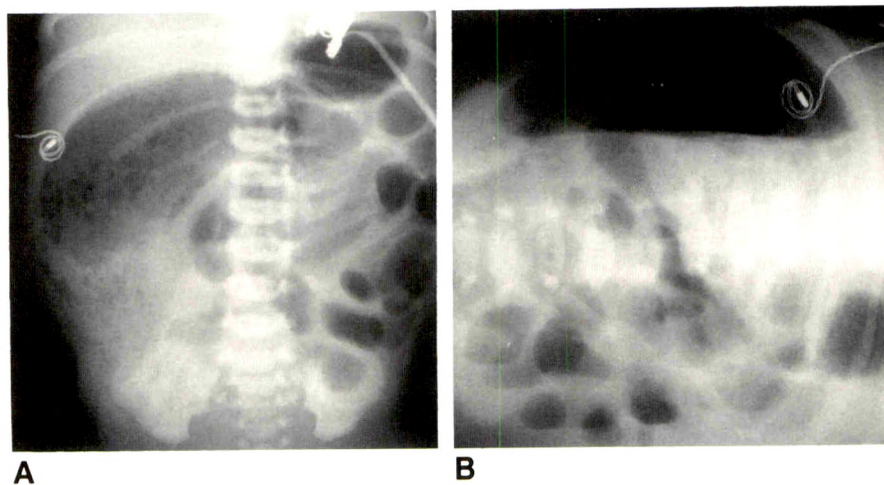


Fig. 5.—Atresia of transverse colon.

A and B, Radiographs with patient supine (A) and in left lateral decubitus position (B) show distended ascending and transverse colon.

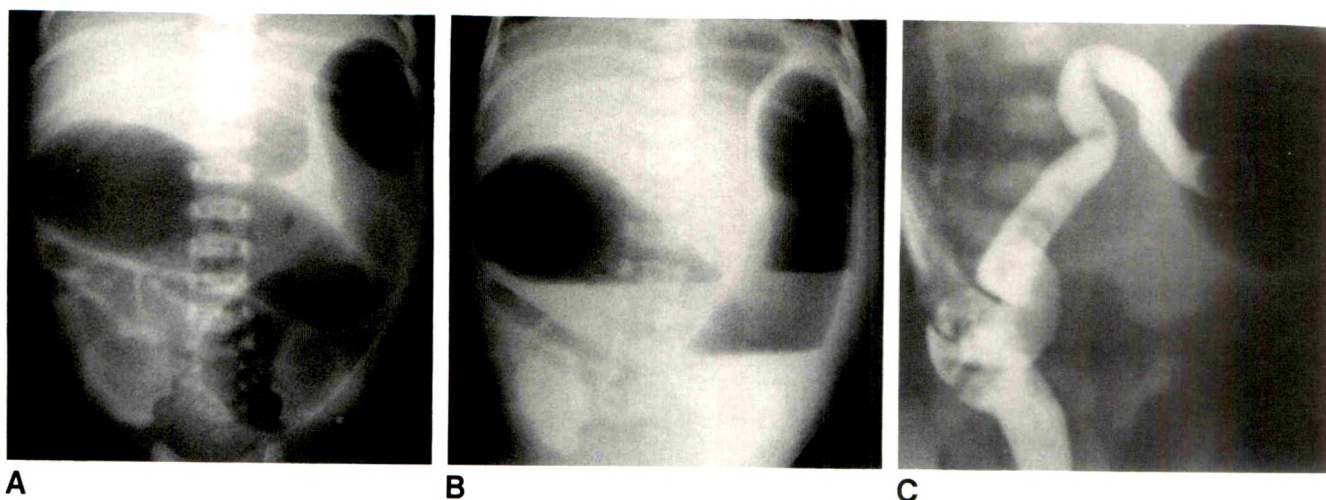


Fig. 6.—Atresia of sigmoid colon.

A and B, Radiographs with patient supine (A) and upright (B) show dilatation of ascending, transverse, and descending colon, with multiple gas/fluid levels.

C, Contrast enema shows that small-diameter distal sigmoid colon terminates adjacent to distended proximal sigmoid colon. Type I atresia was found at surgery.

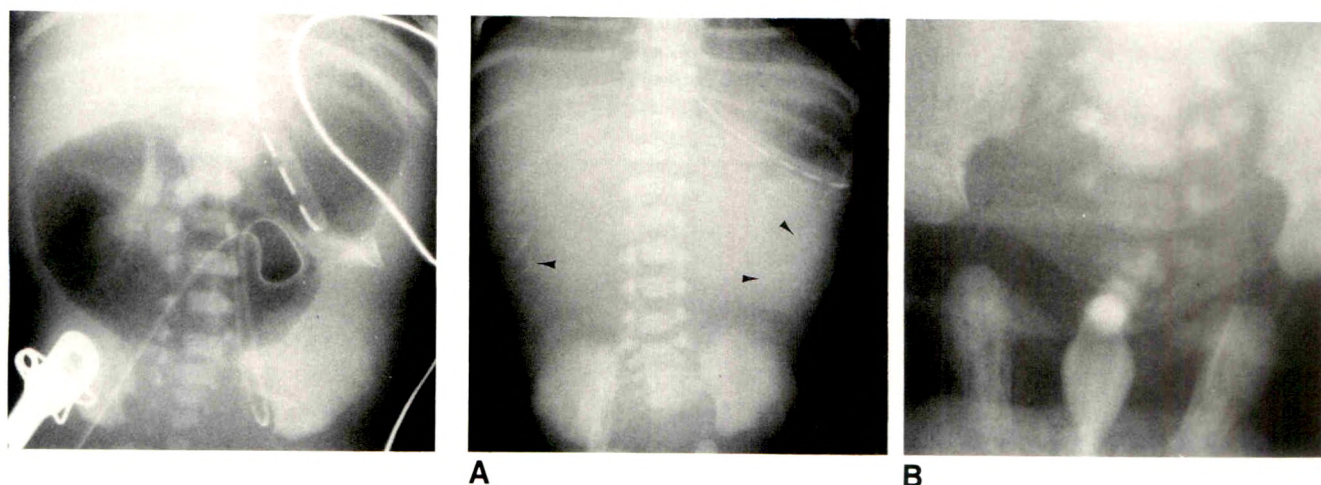


Fig. 7.—Multiple intestinal atresias. Radiograph of abdomen with patient supine shows gas-filled stomach and duodenum, with no gas seen distally. Atresias of proximal jejunum, ascending colon, and sigmoid colon were found at surgery.

Fig. 8.—Multiple intestinal atresias.

A, Radiograph with patient supine shows that only gas in abdomen is a small amount of air in stomach. Intramural intestinal calcification (arrowheads) and antral web were found at surgery.

B, Contrast enema shows opacification of a small rectum and distal sigmoid colon. Colon was found to be almost completely atretic at surgery.

in utero, leading to the current belief that atresia of the colon is caused by vascular accidents in utero.

The purpose of this pictorial essay is to show several radiographic patterns typical of atresia of the colon, and to illustrate how contrast studies of the colon can be used to locate the level of atresia and exclude the presence of additional, unsuspected atresias. Material for this report was selected from radiographic studies of 17 neonates with atresia of the colon who were seen at our hospital in the past 20 years.

Type I Atresia

Type I atresia of the colon is characterized by an obstructing intraluminal membrane (Fig. 1). A contrast enema shows a

small-diameter colon to the level of obstruction and may show a characteristic bulging at the site of obstruction, the "wind sock" sign (Fig. 2).

Proximal Atresia

In our series, atresias of the ascending and transverse colon were more common than those distal to the splenic flexure. The location of the atresia is important because proximal atresias are usually treated by excision of the atretic segment and primary reanastomosis, whereas distal atresias are initially treated by creation of an ileostomy [4].

The ascending colon may become distended if it is atretic and the ileocecal valve is competent. Abdominal radiographs

of neonates with an atresia of the ascending or transverse colon in most cases show a markedly dilated right-sided intestinal loop, with a large gas/fluid level on horizontal beam views. A contrast study of the colon shows a small-diameter colon that terminates adjacent to the dilated right-sided loop (Figs. 3–5).

Distal Atresia

Atresias distal to the splenic flexure are unusual. Abdominal radiographs usually show dilatation of loops of the ascending, transverse, and descending colon, with gas/fluid levels seen on upright or decubitus views. Contrast enemas opacify a variably short length of small-diameter colon (Fig. 6).

Multiple Intestinal Atresias

Atresias of the colon may occur with additional atresias of the intestinal tract, as well as with other abnormalities such

as gastroschisis (Figs. 7 and 8). Because swallowed air can progress only to the level of the most proximal atresia, more distal atresias will not be apparent as dilated, gas-filled loops on radiographs. When radiographs suggest atresia of the small bowel, contrast study of the colon can be used to exclude the presence of additional, more distal atresias before surgery.

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New Format for Abstracts

Beginning in Fall 1992, the *AJR* will publish abstracts of articles in a different format, much like the ones recently adopted by the *New England Journal of Medicine* and the *Journal of the American Medical Association*. The purpose of the new design is to have abstracts present the essential elements of articles more clearly and concisely. The contents, organization, and length of the abstracts will be the same as before; however, rather than being all one paragraph except for the conclusion, abstracts will now be divided into four paragraphs, each with a title: objective, subjects (or materials) and methods, results, and conclusion.

The *AJR* Guidelines for Authors, which appears at the front of every issue of the Journal, has been revised to help you write abstracts in this new format. Authors should familiarize themselves with these guidelines and incorporate them into all manuscripts submitted for publication.

Robert N. Berk
Editor-in-Chief

Case Report

Transjugular Intrahepatic Portosystemic Shunt in a Child with Cystic Fibrosis

Scott R. Kerns¹ and Irvin F. Hawkins, Jr.

We report a case of a 13-year-old girl with cystic fibrosis that manifested as cirrhosis, portal hypertension, and variceal bleeding. A transjugular intrahepatic portosystemic shunt was performed successfully with no recurrent hemorrhages.

Case Report

A 13-year-old girl with cystic fibrosis was referred to our service after multiple episodes of upper gastrointestinal hemorrhage. Pulmonary manifestations were mild, consisting only of shortness of breath with increased activity. She had had six to seven episodes of variceal bleeding due to portal hypertension from cirrhosis, and sclerotherapy had failed numerous times. The nature of this progressive congenital illness and her mother's reluctance prevented a surgical portosystemic shunt or liver transplantation.

Physical examination showed that she was small for her age, had hepatosplenomegaly, and had clubbing of the fingers. No jaundice or ascites was present. Laboratory values included a low hematocrit of 30% (0.30) and mildly elevated prothrombin time (13.2 sec) and partial thromboplastin time (42 sec.) Total protein and albumin levels were normal at 7.1 g/dl (71 g/l) and 3.8 g/dl (38 g/l), respectively. However, results of liver function tests were abnormal: the aspartate aminotransferase level was 121 U/l, alanine aminotransferase level was 63 U/l, and total bilirubin level was 1.6 mg/dl (27 μ mol/l). Her condition was considered Child class A.

A transjugular intrahepatic portosystemic shunt was requested to alleviate the portal hypertension. The right internal jugular vein was punctured under sonographic guidance, and after serial dilatation, a 12-French guiding catheter was placed into the right hepatic vein. A blunt-tipped modified Ross needle was used to direct a sharp 21-gauge Hawkins needle guide (Cook, Bloomington, IN) anteriorly through the liver parenchyma under fluoroscopic guidance. The main

portal vein had been marked on the anterior abdominal wall with an ECG electrode by using sonographic guidance to provide a target during fluoroscopy. The portal venous system was entered initially with the needle guide, over which an 8-French catheter and 12-French guiding catheter were advanced into the portal vein. Initial pressures measured were 50 mm Hg/36 mm Hg. The track balloon dilated with a 5-mm- and then a 6-mm-diameter angioplasty balloon (Medi-tech, Watertown, MA) and stented with a 42-mm Wallstent self-expanding metallic prosthesis (Schneider, Minneapolis, MN; Fig. 1A), which lowered the portal venous pressure to 36 mm Hg/31 mm Hg. Portography showed brisk flow through the shunt without filling of esophageal varices (Fig. 1B).

The child has been followed up for the past 6 months both clinically and with color Doppler flow sonography. The shunt has remained widely patent, and no further bleeding has occurred. A single episode of encephalopathy was treated easily by altering the lactulose dosage and dietary restrictions.

Discussion

Cystic fibrosis is an inherited disorder of the exocrine glands that results most prominently in abnormalities of the alimentary tract, pancreas, and lungs. Biliary cirrhosis may develop in the liver as a result of mucous plugging of the bile ducts followed by portal fibrosis. Advanced changes in the liver, as portrayed in this case, occur in less than 5% of patients with cystic fibrosis, but when present they can lead to portal hypertension and bleeding varices. Because of coexistent lung disease, poor nutritional status, and a propensity to infections, these patients are poor candidates for surgical portosystemic shunts or liver transplantation.

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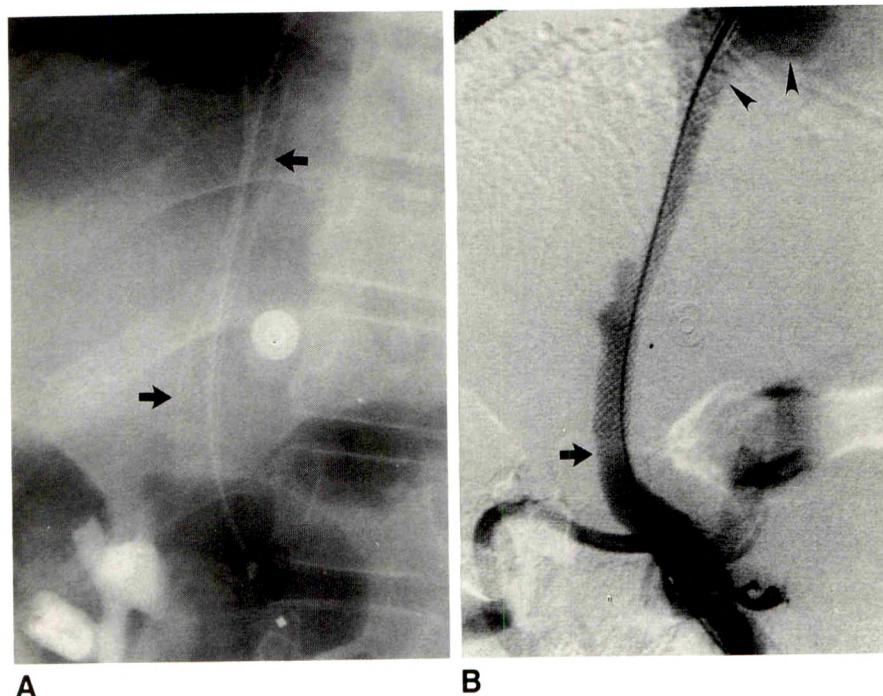


Fig. 1.—A, Radiograph shows Wallstent prosthesis (arrows) connecting hepatic and portal venous systems.

B, Portogram shows brisk flow through shunt from portal vein (arrow) to hepatic vein and right atrium (arrowheads).

Transjugular intrahepatic portosystemic shunts have recently become a practical alternative to surgical portosystemic shunting for decompression of portal hypertension and treatment of variceal bleeding refractory to medical management and sclerotherapy. Although Colapinto et al. [1] first described creating a portosystemic shunt in humans by a nonsurgical approach in 1982, the technique of percutaneous transjugular shunting has only recently been widely accepted. The use of metallic stents to maintain patency has vastly improved the efficacy of the procedure [2].

Although the long-term outcome of transjugular intrahepatic portosystemic shunts has yet to be determined, the short-term effects appear promising. Shunt patency appears high, and if the shunt thromboses, it can be reopened percutaneously via a transjugular approach. Even though most investigators have performed this procedure on more critically ill

patients in Child B or C condition, the observed morbidity and mortality of the procedure are lower than those for surgical portosystemic shunts [3]. This case demonstrates a new option for those caring for children with cystic fibrosis or other conditions that lead to cirrhosis and portal hypertension.

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**Determination of Magnetization
Transfer Contrast in Tissue:
An MR Imaging Study of Brain Tumors**

Nina Lundbom¹

OBJECTIVE. In this study, the magnetization transfer contrast (MTC) on MR images of several brain tumors and the correlation between MTC and tumors' histologic features were investigated. MTC depends on the extent of magnetization transfer, or cross-relaxation, from tissue water protons to macromolecular protons. On the basis of the known increase of the cross-relaxation rate with increasing molecular weight of protein in protein solutions, the hypothesis that changes in MTC correlate directly with the macromolecular composition of various tumors was tested.

SUBJECTS AND METHODS. Preoperative MR images were obtained with a 0.1-T MR system in 40 patients with brain tumors. MTC was correlated with the histologic features and the dry weight of the tumors. The tumors studied included astrocytomas (10), acoustic schwannomas (three), meningiomas (12), pituitary adenomas (10), craniopharyngiomas (two), and hemangioblastomas (three).

RESULTS. MTC was 0.43 in normal white matter and 0.42 in normal gray matter, and varied from 0.11 to 0.37 in the tumors. The mean MTC in astrocytomas (0.21 ± 0.09) was smaller than the mean MTC in the gray matter ($p = .0001$) or in the other solid tumors (0.34 ± 0.07 to 0.37 ± 0.09 , $p < .002$). MTC was larger in high-grade than in low-grade astrocytomas (0.28 ± 0.05 vs 0.14 ± 0.04 , $p = .0005$). In meningiomas, MTC correlated with the collagen content of the tumor tissue ($r = .95$, $p = .01$). The differences in contents of solids between the solid tumor groups were not significant ($p \geq .1$, NS).

CONCLUSION. When the previously demonstrated correlations between solid content and $1/T_1$ of the types of tumors studied are taken into consideration, the present results suggest a larger relative contribution from hydrodynamic vs cross-relaxation effects in astrocytomas than in benign tumors or in gray matter. The twofold difference in MTC between low- and high-grade astrocytomas probably reflects the amount of nuclear material in the tumor cells. Collagen content determined the differences in MTC among meningiomas. These results indicate that the major determinant of differences in MTC within these tumor groups is the high-molecular-weight tissue macromolecules, suggesting higher specificity for MTC than for T_1 in discriminating between tissues on MR images.

AJR 159:1279-1285, December 1992

In conventional MR imaging, image contrast is a function of the inherent spin-lattice (T_1) and spin-spin (T_2) relaxation times of protons on tissue water and fat molecules, and of their proton density. However, the ability of MR imaging to show differences between tissues on the basis of these factors is limited. Efforts to improve differentiation between tissues on MR images have recently led to the development of imaging with magnetization transfer contrast (MTC) [1], which is sensitive to the extent of magnetization exchange, or cross-relaxation [2-6] in tissue. MTC imaging has been shown to improve tissue contrast [7], and the tissue dependence of magnetization exchange has been demonstrated with this technique [7-9]. This suggests that the MTC technique could be used to provide quantitative information on tissue relaxation also. In protein solutions, the cross-relaxation rate has been shown to increase with increasing molecular weight of the protein [10, 11]. This study was designed to test the proposed correlation between cross-

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relaxation and molecular weight [10, 11] in tissues; MTC in brain tumors and possible correlations with the tumors' histologic features were investigated.

Subjects and Methods

Imaging Sequences

Forty consecutive patients with brain tumors were studied preoperatively during a 1-year period. Informed consent was obtained from each patient. A 0.1-T MR system (Mega4, Instrumentarium, Helsinki, Finland) was used to obtain spin-echo (SE) 2100/120 and precontrast and postcontrast partial saturation, three-dimensional (PS 3D) 50/22 images through the brain. MTC images were generated at the level of the largest tumor diameter, with a TR of 1000 or 1500 msec and a TE of 20 or 60 msec. An 8-kHz off-resonance RF pulse of 500 msec was used, resulting in a specific absorption rate of 0.22 W/kg. The method used two concurrently obtained gradient-echo images generated without and with a saturation pulse, here referred to as preirradiation and postirradiation images. For the first 36 patients, a gradient-echo sequence with TR/TE of 1000/20 was used, giving the magnetization transfer (MT) 1000/20(500) [TR/TE(RF pulse length)] image pair. Five of these patients were imaged, in addition, with an MT 1500/60(500) sequence, combining MTC with T2-weighting, and for four patients only an MT 1500/60(500) sequence was used.

Histologic Features, Dry Weight, and Estimation of Collagen Content

Tumors included three acoustic schwannomas, 10 astrocytomas (two grade I, four grade II or II-III, four grade III or IV), two craniopharyngiomas, three hemangioblastomas, 12 meningiomas (three fibroblastic, eight transitional, one meningothelial), and 10 pituitary adenomas (four prolactinomas, three somatotropinomas, two prolactinoma-somatotropinomas, one thyrotropinoma). The percentages of dry weight of the tumors were determined by weighing the tumor samples (obtained at surgery) before and after they were dried in an oven at 80°C to constant weight. The relative amount of collagen in the meningiomas was estimated morphometrically by projecting the microscopic view of the van Gieson-stained slides on a point-counting grid and then determining the proportion of red-staining collagen from

the total area of tumor tissue. The total collagen content of the meningioma samples was calculated by multiplying the percentage of solids by the estimated fraction of collagen.

Determination of Magnetization Transfer Contrast

Signal intensities were measured on the preirradiation and postirradiation MTC images in normal and edematous white matter, gray matter, CSF, and tumor tissue, both necrotic and viable, by using the region-of-interest (ROI) technique. The necrotic tumor areas of grade IV astrocytomas were defined as those inside a ring-enhancing (viable) tissue in the contrast-enhanced images. MTC was calculated as $1 - (M_s/M_o)$, where M_o is the bulk water steady state magnetization without irradiation, and M_s is the bulk water magnetization after irradiation of the macromolecular protons.

Statistics

A paired t-test was used to compare MTC obtained with the MT 1000/20(500) and MT 1500/60(500) sequences, both in white matter and in tumors. The significance of the difference between means of MTC in astrocytomas, meningiomas, pituitary adenomas, and gray matter, between high- and low-grade astrocytomas, and between somatotropinomas and prolactinomas was tested by using a two-tailed, unpaired t-test. Linear regression analysis was used to test correlations between MTC and content of solids and MTC and total collagen content in meningiomas and the correlation between MTC and content of solids in pituitary adenomas. All given differences between groups marked NS were nonsignificant at the $p \geq .1$ confidence limit.

Results

Figures 1 to 5 show T2-weighted SE 2100/120 and MT preirradiation and postirradiation images of grade I, III, and IV astrocytomas, a meningioma, and a pituitary adenoma. The sequences with a TR/TE of 1000/20 resulted in suboptimal image contrast (Figs. 1 and 3), while the MT 1500/60(500)

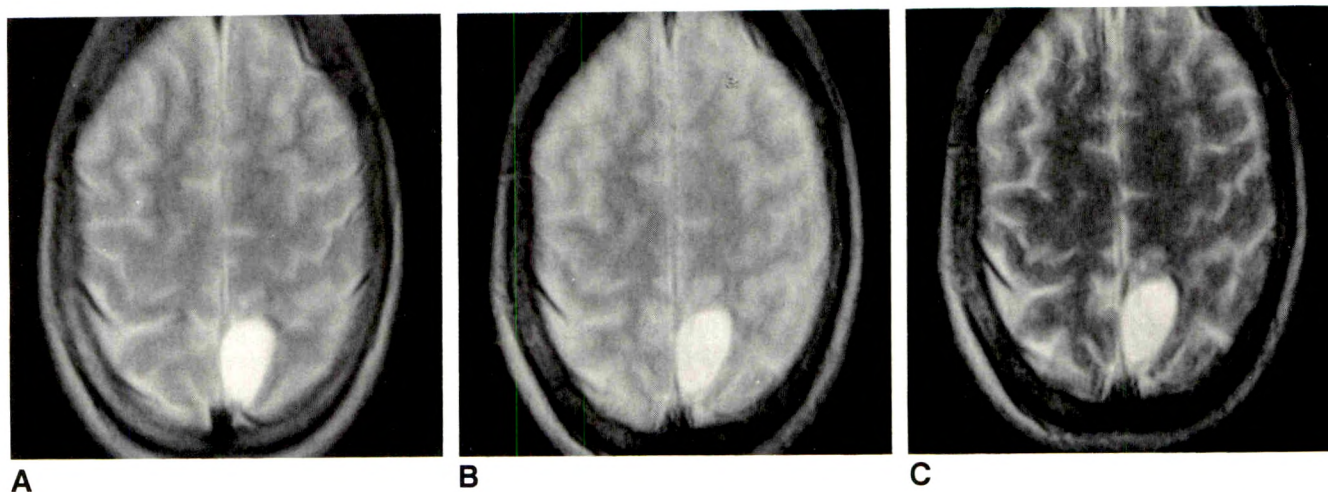


Fig. 1.—A–C, Grade I astrocytoma. SE 2100/120 MR image (A), and MT 1000/20 (500 msec RF pulse) MR images obtained before (B) and after (C) irradiation. Signal loss with irradiation pulse (B to C) is greater in normal brain tissue than in tumor, resulting in improved tumor-brain contrast on postirradiation image (C).

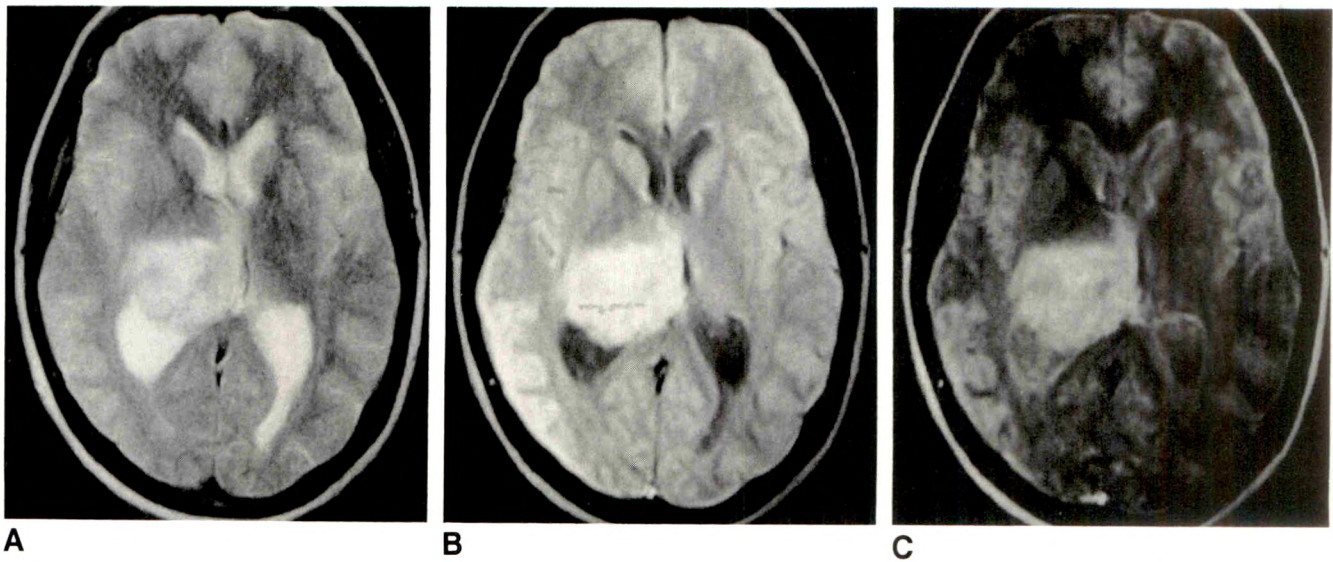


Fig. 2.—A–C, Grade III astrocytoma. SE 2100/120 (A), and MT 1500/60 (500) images obtained before (B) and after (C) irradiation. Combination of MTC with T2-weighting is shown in B and C. Both normal brain tissue and tumor lose signal after irradiation.

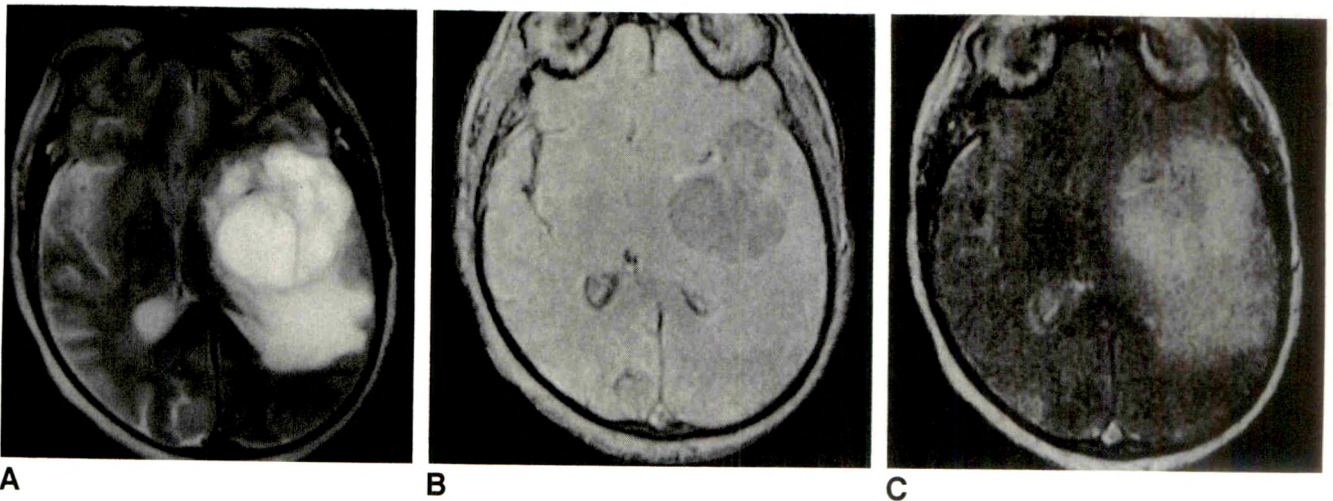


Fig. 3.—A–C, Grade IV astrocytoma. SE 2100/120 (A) and MT 1000/20 (500) images obtained before (B) and after (C) irradiation. Irradiation-induced signal loss is smaller in surrounding edematous brain tissue than in normal brain tissue. In tumor, necrotic inner part loses little signal, whereas border area, corresponding to ring-enhancing tissue in postcontrast images (not shown), loses more. SE 2100/120 image (A) shows both tumor and surrounding edema.

images (Figs. 2, 4, and 5) had better signal relative to noise and contrast relative to noise. No difference was found between the sequences in the calculated mean MTCs of the white matter (NS) or of the five tumors (NS) imaged with both sequences.

The effect of the saturation pulse (i.e., signal contrast between the preirradiation and postirradiation images) was most pronounced in the normal brain tissue (Table 1). MTC was smaller in edematous white matter and in CSF. The tumors studied could be divided into two groups according to the effectiveness of MT; MTC in the tumor was either smaller than in the gray matter or did not significantly differ from it (pituitary adenomas vs gray matter, $p = .06$, NS). The mean measured MTC was lower in the craniopharyngiomas, hemangioblastomas, and astrocytomas than in the meningi-

omas, acoustic schwannomas, and pituitary adenomas. The mean MTC in astrocytomas was significantly lower than in meningiomas ($p = .002$) or in pituitary adenomas ($p = .0008$), but the MTCs of meningiomas and pituitary adenomas did not differ (NS). The average content of solids in the solid tumor groups, when it was measured, was 16–19% (Table 1). The measured differences between the content of solids in the solid tumor types were not significant (between pairs of groups, NS).

The estimated relative amount of collagen in the histologic sections of the meningioma samples varied from 12% to 61%. The approximated total collagen content of the tumor tissue was between 2% and 8% and correlated with the observed MTC ($r = .95$, $p = .01$; Fig. 6), whereas no correlation was found between tumors' content of solids and MTC (NS).

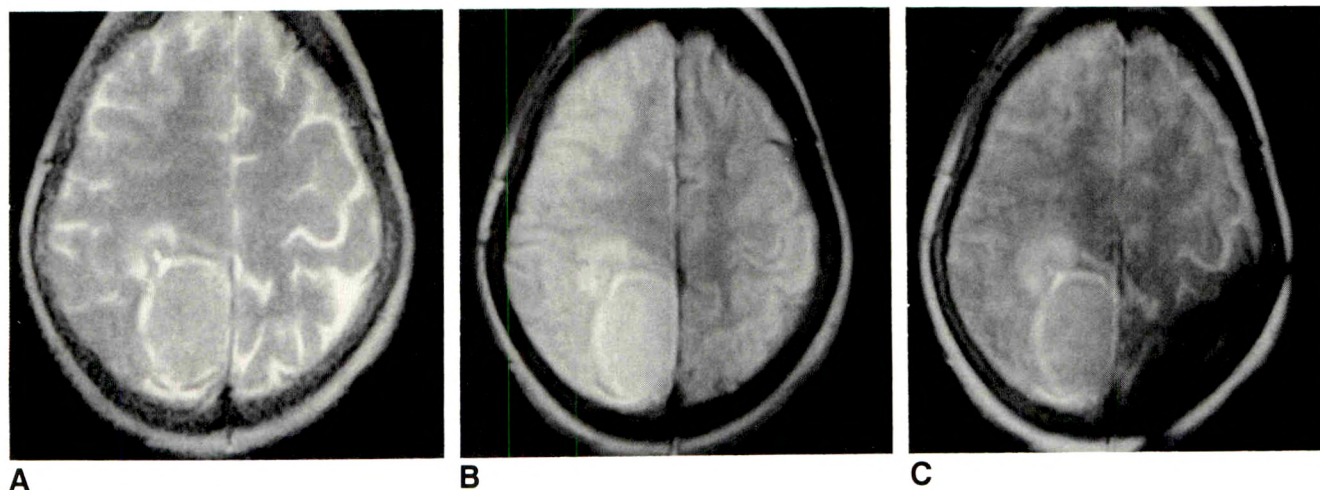


Fig. 4.—A–C, Meningioma. SE 2100/120 (A) and MT 1500/60 (500) images obtained before (B) and after (C) irradiation. Loss of signal intensity after irradiation is obvious in both tumor and normal brain tissue.

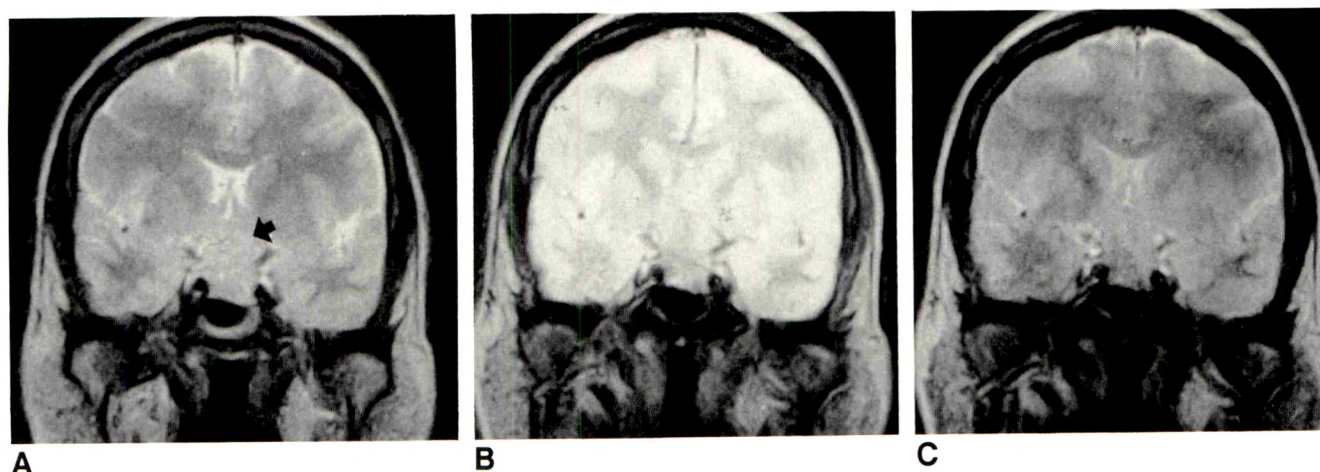


Fig. 5.—A–C, Pituitary adenoma, a somatotropinoma-prolactinoma (arrow). SE 2100/120 (A) and MT 1000/20/(500) images obtained before (B) and after (C) irradiation. Both tumor and normal brain tissue lose signal after irradiation, and tumor-brain contrast is not improved.

In astrocytomas, MTC was smaller than in other solid tumors or in gray matter (Table 1). In grade I and II astrocytomas, MTC was 0.14 ± 0.04 ; in grade III and IV tumors it was higher, 0.28 ± 0.05 ($p = .0005$; Table 2 and Fig. 7).

In pituitary adenomas, no significant differences were found between the MTC of somatotropinomas and the MTC of prolactinomas. No correlation was found between MTC and tumors' content of solids (NS).

Discussion

In recent studies [6–11, 13, 14], cross-relaxation through magnetization exchange between mobile water protons and protons on macromolecules of restricted motion has been considered a dominant contributor to relaxation in tissues. Both through-space dipolar interactions [2, 3, 5] and chemical exchange [15] between water and macromolecular protons

have been proposed as mechanisms for this exchange. In addition, hydrodynamic effects [3, 16] contribute to relaxation. Proposed theories have suggested that magnetization is transported within the "solid" macromolecules through spin diffusion and cross-relaxation [17] and in the water component through diffusion of water molecules [18]. Koenig et al. have concluded from nuclear MR dispersion (NMRD) studies on model systems of tissue (Koenig SH et al., presented at the Society of Magnetic Resonance in Medicine [SMRM] meeting, August 1991) that immobilization of macromolecules by cross-linking is the key point for magnetization transfer in tissue, so that proton relaxation in the macromolecules occurs as in the solid rather than the liquid state. The MTC technique provides a means to probe the magnetic coupling between the liquid and solid components of tissue [1, 7]. Consequently, MTC measurement of cross-relaxation in tissues may provide information on the structure of the immobilized, normally unobserved, solid tissue component.

TABLE 1: Effect of the Saturation Pulse on MR Image Signal Intensity of Normal Brain Tissue and of Brain Tumor and the Dry Weight of the Tissues Studied

Tissue or Tumor	Magnetization Transfer Contrast		% Dry Weight	
	No. of Tumors	Mean $\pm$ SD	Mean $\pm$ SD	No. of Tumors
White matter	36	0.43 $\pm$ 0.04	28	—
Gray matter	12	0.42 $\pm$ 0.05	18	—
White matter, edematous	11	0.24 $\pm$ 0.10	—	—
CSF	10	0.07 $\pm$ 0.08	—	—
Pituitary adenoma	10	0.37 $\pm$ 0.09	18.8 $\pm$ 3.1	6
Acoustic schwannoma	3	0.36 $\pm$ 0.13	—	—
Meningioma	10	0.34 $\pm$ 0.07	17.8 $\pm$ 3.5	5
Astrocytoma	10	0.21 $\pm$ 0.09	16.0 $\pm$ 4.3	3
Hemangioblastoma	3	0.14 $\pm$ 0.10	—	—
Craniopharyngioma	2	0.11 $\pm$ 0.08	—	—

Note.—Magnetization transfer contrast is expressed here as $1 - (M_s/M_0)$, where M_0 and M_s are signal intensities in preirradiation and postirradiation images, respectively. Percentages of dry weight for white and gray matter are from Norton [12]. Dash = not measured. Differences in magnetization transfer contrast between tumor groups: astrocytoma < meningioma ($p = .002$), astrocytoma < pituitary adenoma ($p = .0008$), and meningioma vs pituitary adenoma ($p = .4$, NS). Differences in % dry weight between tumor groups: astrocytoma vs meningioma ($p = .3$, NS), astrocytoma vs pituitary adenoma ($p = .1$, NS), and meningioma vs pituitary adenoma ($p = .2$, NS).

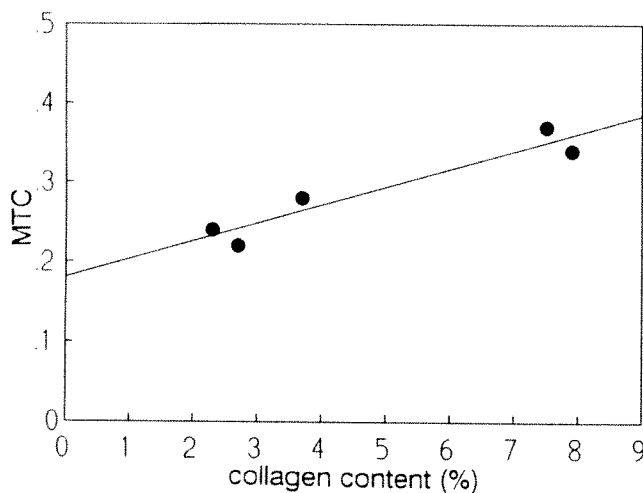


Fig. 6.—Graph shows correlation between magnetization transfer contrast (MTC) and collagen content in five meningiomas ($r = .95$, $p < .01$).

Current investigations on neoplastic tissues have shown that in many brain tumors the main determinant of $1/T_1$ is the tissue's content of solids [20]. The inability of MR imaging to show the difference between different tumors on the basis of T_1 has thus been explained at the cellular level, as the content of solids of various tumors types and grades of malignancy overlap. The MTC method can be expected to provide information about neoplastic changes, if the macromolecular structure of the neoplastic tissue is sufficiently altered. Koenig and Brown showed from their own data [11] and from the data of Zhong et al. [10] that the relative contribution from cross-relaxation increases more rapidly than does the surface area of a protein in a solution. Thus, it can be predicted that the correlation between MTC and the dominant molecular weight will be exponential rather than linear in tissues as well.

MTC, which depends on the magnitude of the macromole-

TABLE 2: Magnetization Transfer Contrast in Astrocytomas Showing the Effect of the 500-msec Saturation Pulse on MR Image Signal Intensity

Patient's Sex/Age (yr)	Grade	Enhancement	MTC
F/21	I	-/+	0.09
M/29	I	—	0.17
F/29	II	—	0.13
M/27	II	—	0.19
F/42 ^a			
Region 1	II	—	0.10
Region 2	III	+	0.34
M/46 ^b	II	—	0.17
F/43	III	+	0.26
F/44	III	+	0.34
M/55 ^c			
Region 1	IV	+	0.25
Region 2		—	0.04
M/75 ^c			
Region 1	IV	+	0.22
Region 2		—	0.46

Note.—Magnetization transfer contrast (MTC) = $1 - (M_s/M_0)$, where M_0 = signal intensity in the preirradiation image, and M_s = signal intensity in the postirradiation image.

^a Tumor was multicentric and consisted of both nonenhancing and enhancing regions, corresponding to shown histologic grades.

^b Oligoastrocytoma.

^c Region 2 is nonenhancing inner part of tumor.

cule-water interaction [1], is defined as the decrease in signal intensity between preirradiation and postirradiation images, and is given by the equation $1 - (M_s/M_0) = k_a \times T_{1a}$, where k_a is the rate of magnetization transfer from water to macromolecules [19], and T_{1a} is the apparent T_1 of the bulk water pool measured after irradiation. Consequently, MTC alone does not represent the quantitative magnetization transfer rate in tissue [8, 19]. Determination of T_{1a} and k_a would prolong imaging time, and therefore in this study with clinical patients, only MTC was measured.

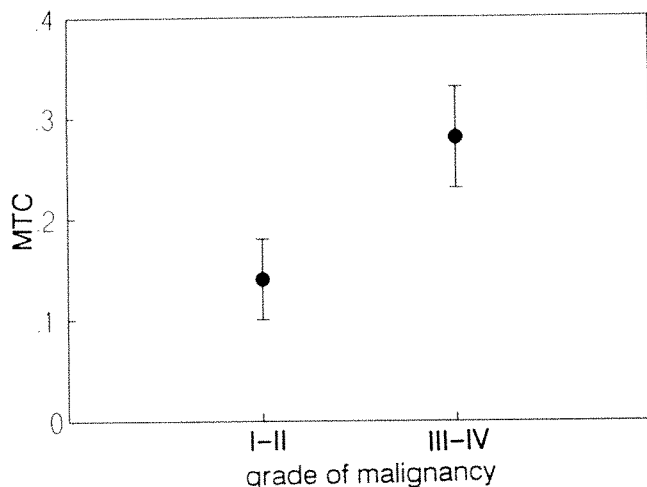


Fig. 7.—Graph shows correlation between magnetization transfer contrast (MTC) and grade of malignancy in astrocytomas. MTC data on individual tumors are given in Table 2. Measurements from necrotic tissue (nonenhancing area inside ring-enhancing grade IV tumor) are not included. For high-malignancy grade III and IV tumors ($n = 5$), mean MTC was 0.28 ± 0.05 ; for low-malignancy grade I and II tumors ($n = 6$), mean MTC was 0.14 ± 0.04 ($p = .0005$).

Brain Tissue

White matter, as expected [6, 14], but also gray matter, had a larger MTC (0.43 and 0.42, respectively), than any of the tumor groups had. This agrees with the results of Wolff et al. [7], who measured magnetization transfer in a cat's brain in vivo at 4.7 T and found that M_s/M_0 was about 0.6 in gray matter and about 0.5 in white matter. White matter has been shown to have a considerable cross-relaxation contribution between the rapidly relaxing myelin-lipid bilayers and myelin and axonal waters [6, 14]. In the gray matter, no comparable source for cross-relaxation exists, and still the two show similar MTC effects. Because of the shorter T1 at low fields [6], diffusion of water across the myelin fibers of white matter is more restricted [21] in a T1 time scale at 0.1 T than at higher fields [6]. This may be a limiting factor for MTC of white matter in this study. The small MTC in CSF is in accordance with previous studies [1, 7], where it was concluded that the smaller decrease in signals of blood and CSF than in tissues indicated a slow magnetization exchange due to a small number of macromolecules. Similarly, the small MTC in the edematous white matter mainly reflects dilution in the macromolecular component of tissue.

Tumors

The MTC of the tumors was smaller than or about the same as the MTC of the gray matter (Table 1). In craniopharyngiomas and hemangioblastomas, the MTC is small because the tumor has an abundant liquid component; craniopharyngiomas contain fluid rich with cholesterol, and hemangioblastomas are largely lipid- and fluid-filled cystic structures [22]. Among the solid tumors, the content of solids can be considered in pituitary adenomas, meningiomas, and astro-

cytomas only. The dry weights (Table 1) agree with those published by Englund et al. [23] and Just et al. [24], who found that the mean content of solids was 14% in low-grade astrocytomas, 18% in high-grade astrocytomas [23], and 18% in meningiomas [24]. No reference values for the content of solids of pituitary adenomas have been published. The differences in the MTCs of all solid tumors studied are large compared with the differences in their respective contents of solids (Table 1), supporting the view that the nature of the macromolecular component is an important factor in determining MTC in tissue.

MTC was smaller in astrocytomas than in gray matter ($p = .0001$) or in other solid tumors, despite the small differences in the content of solids of these tissues (Table 2), indicating a smaller exchange of magnetization in astrocytomas. In a relaxometry study of brain tumors, Lundbom et al. [20] concluded that the predominant determinants of relaxation in low-grade astrocytomas are cytoplasmic, and those in high-grade astrocytomas are nuclear. In that study, the ratio of $1/T1$ to solids was constant and insensitive to tumor type or grade of malignancy in astrocytomas, despite the differences in the macromolecular constituents that cause relaxation of tissue water. A comparison between $1/T1$ vs grade of malignancy (Fig. 6 of Lundbom et al. [20]) and MTC vs grade of malignancy (Fig. 7, this study) suggests the greater potential of MTC compared with $1/T1$ for differentiating between astrocytomas of different grades. The finding that MTC was larger in high-grade than in low-grade astrocytomas suggests that MTC may reflect the amount of high-molecular-weight nuclear material, which is known to be greater in high-grade astrocytomas [25–27].

In the meningiomas, MTC correlated with the estimated collagen content of the tumor (Fig. 6). Elster et al. [28] and Just et al. [24] found, from studying 40 and 21 meningiomas imaged at 0.15–1.5 T and 0.28 T, respectively, shorter T2s, T1s, or both in fibroblastic and transitional than in meningotheial meningiomas. These studies [24, 28] suggest that fibroblastic and transitional meningioma subtypes must have an additional source for relaxation compared with the meningotheial subtype. Collagen, a typical feature of fibroblastic and, to a variable degree, of transitional meningiomas, but occurring in minimal amounts in the meningotheial type [22, 28], was found to be a major factor in determining differences in MTC among meningiomas. This finding is supported by the results of Spiller et al. (SMRM meeting, August 1991), who studied NMRD profiles of brain tumors, and found that cross-relaxation dominated $1/T1$ for some meningiomas above about 1 MHz. Collagen was shown to be an important determinant of relaxation times in skeletal muscle and tendon in an in vitro study by Scholtz et al. [29], and it dominated magnetization transfer of articular cartilage in another in vitro study (Kim DK et al., SMRM meeting, August 1991). The characteristics of collagen responsible for magnetization transfer have not been established, although both the large molecular size and extensive intramolecular and intermolecular cross-linking [5, 11, 29, 30] must be important.

Among the tumors studied, pituitary adenomas had the largest MTC. This is in agreement with the results of Spiller et al. (SMRM meeting, August 1991), who reported high

1/T1 relaxation rates per unit solids, dominated by cross-relaxation, for hormone secreting pituitary adenomas. They reported that the type and level of hormone secretion may influence proton relaxation. Neither their work nor this study allows a determination of the source of cross-relaxation in pituitary adenomas. However, both the secreted hormones and their precursor molecules have a molecular weight of 20,000–30,000 [31]; thus these proteins are too small to transfer magnetization efficiently [11] and can be expected to contribute mostly through hydrodynamic effects.

This study showed that, as expected [1], the MTC method can provide new information on water relaxation in neoplastic tissue. It also showed that MTC can be used in addition to conventional T1- or T2-weighted, or proton density-weighted sequences to improve contrast between tumors and normal brain tissue on MR images. The correlation between MTC and grade of malignancy in astrocytomas suggests that the variation in MTC among astrocytomas may well arise from differences in the amount of nuclear material. This should be confirmed by concurrent MTC and DNA-flow cytometry studies. The relative contributions that arise from hydrodynamic and cross-relaxation for tumors and for normal brain tissue must be resolved to understand better the factors that differentiate neoplastic from normal tissue in MR and MTC imaging.

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Book Review

Current Opinion in Radiology. Neuroradiology and Radiology of the Head and Neck: 1992. Guest editors: A. James Barkovich, Thomas J. Vogl, and William P. Dillon. Philadelphia: Current Science, February 1992;4(1):1-173. \$30; by subscription, 6 issues annually for \$145

This is one of a continuing series of books on radiology developed with the specific purpose of keeping specialists up-to-date with the current medical literature. This issue is devoted to three major areas: contrast agents, neuroradiology, and head and neck imaging. For each volume in the series, an editorial board reviews a list of primary journals that includes the ones most commonly cited. For each issue of a volume, the guest editor or editors divide the material to be covered into a number of subgroups and asked leading experts in the relevant field to write short review chapters on these topics. The experts also provide short reviews of the papers that have been published in this area in the preceding year. At the end of the book is a complete bibliography of all papers relevant to the entire volume that were included in the publisher's data base. Papers considered to be of special or outstanding interest are identified separately, both in the individual chapters and in the summary bibliography.

I think that this book is successful in reaching its goals and objectives. The organization of subjects is appropriate and is a major strength of the presentation. The editorial overview of neuroradiology is particularly thorough and well written. In fact, this presentation effectively summarizes the major scientific advances of 1991 in fewer than four pages. Each subsequent chapter is five to 10 pages long. Generally, the reviewers have attempted to subdivide their further chapters and then review the appropriate papers relevant to current knowledge in the field. Most of the presentations are excellent, and in some, the authors have interwoven the current status of a topic

and the effect of the new developments with a high degree of expertise. The standard criticism of books with chapters contributed by several different authors is equally true for this text. The quality of the presentations varies significantly. Some of the discussions are nothing more than a paragraph of review of an individual article with no apparent attempt to relate the article to current knowledge. The bibliography reviews also vary, from thorough but brief summaries to occasionally nothing more than a restating of the title of the article. Rarely, an entire chapter is simply a subject review with little or no discussion of new developments. Readers must, however, accept the fact that not all areas have had significant new developments that warrant additional comments. The book has only a few typographic errors, and the quality of the illustrations is excellent.

In summary, I think that the aims of the editors of this book have been admirably achieved. It does provide a way for practitioners in medical or surgical neurology who do not routinely review the radiologic literature to keep abreast of current developments in neuroradiology, and it is certainly unique in its presentation. I think that it will be particularly useful for neuroradiologists involved in teaching and training, and as a guide for fellows and residents in the initial research of a specific topic. It probably would be more useful in a departmental library than in an individual practitioner's personal collection.

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Pleomorphic Xanthoastrocytoma of the Brain: MR Findings in Six Patients

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OBJECTIVE. Pleomorphic xanthoastrocytoma is a rare, usually benign brain tumor. This pleomorphic supratentorial tumor involves the leptomeninges and superficial cortex in young patients with seizures. The MR imaging features of this distinct tumor have not been reported. We describe the MR imaging findings in six patients with pathologically proved pleomorphic xanthoastrocytoma.

MATERIALS AND METHODS. We retrospectively reviewed the MR images of six patients with pathologically proved pleomorphic xanthoastrocytoma. MR images were reviewed by two neuroradiologists. The pathologic slides of the tumors were reviewed by two neuropathologists. We also analyzed the patients' clinical features.

RESULTS. Most of the tumors were cortical based and isointense with gray matter on T1-weighted images and mildly hyperintense on T2-weighted images. All the masses enhanced with contrast material. Cystic components and gyriform and leptomeningeal enhancement were seen occasionally. The tumors occurred in the temporal lobes in four of the six patients. Three patients had seizures, and the other three had headaches.

CONCLUSION. Pleomorphic xanthoastrocytoma is a rare, usually benign, cortical-based mass that often enhances intensely with contrast material. The most common location is in the temporal lobes. Seizures and headaches are common clinical features. Familiarity with this lesion is important in the differential diagnosis of enhancing cortical-based masses.

AJR 159:1287-1290, December 1992

Pleomorphic xanthoastrocytoma was first described by Kepes et al. [1] in 1973. The CT features of these tumors have been described [2-9], but to our knowledge the MR features have not. Accordingly, we retrospectively reviewed the MR images of six patients with pleomorphic xanthoastrocytoma and analyzed the clinical signs and symptoms.

Materials and Methods

We retrospectively reviewed the MR features of four females and two males 12-52 years old (mean, 26 years) who had pathologically proved pleomorphic xanthoastrocytoma. All images had been obtained with GE 1.5-T superconducting magnets (Signa, GE Medical Systems, Milwaukee, WI). For all patients, standard axial and coronal T1-weighted (600/20/1 [TR/TE/number of excitations]) and T2-weighted (2500/30,80/1) images of the brain were obtained. Other parameters were a 20-cm field of view and a 5-mm slice thickness with an interslice gap of 2.5 mm. T1-weighted images were also obtained after injection of gadopentetate dimeglumine (0.1 mmol/kg; Magnevist, Berlex, Cedar Falls, NJ). The images were reviewed by two neuroradiologists. The pathologic slides of the tumors were reviewed by two neuropathologists. We correlated the MR and pathologic findings with the clinical symptoms and signs.

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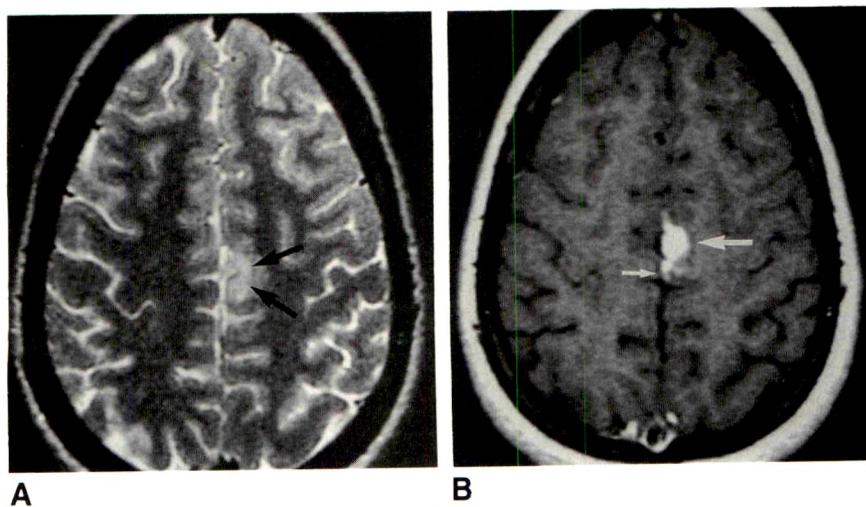


Fig. 1.—16-year-old girl with pleomorphic xanthoastrocytoma who had seizures.

A, Axial T2-weighted (2800/80/1) MR image shows a small area of high signal (arrows) adjacent to cortex of medial left parietal lobe. Axial T1-weighted image without contrast material at the same level did not show any abnormality.

B, Axial T1-weighted (600/20/1) MR image with contrast material shows an enhancing mass (long arrow). Adjacent leptomeninges are also enhanced (short arrow).

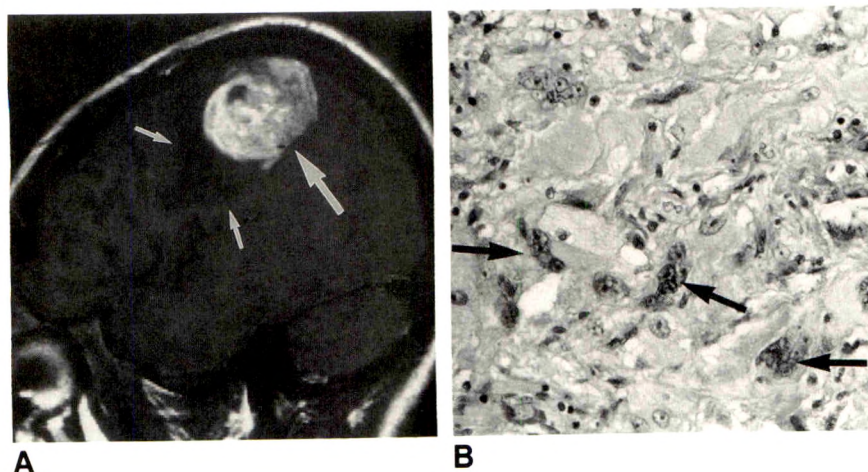


Fig. 2.—18-year-old woman with pleomorphic xanthoastrocytoma who had headaches.

A, Parasagittal T1-weighted (600/20/1) MR image with contrast material shows a large, inhomogeneously enhancing parietal mass (large arrow) abutting cortical surface. Note also surrounding peritumoral low-signal edema (small arrows).

B, Photomicrograph of pathologic specimen shows markedly pleomorphic cells (arrows) without evidence of mitotic activity, necrosis, and vascular proliferation in largest portion of tumor. However, a small region of mass has histologic features of anaplastic astrocytoma. Four months after total resection of tumor, follow-up MR image showed tumor recurrence. (H and E, original magnification $\times 320$)

Results

Five of six tumors were cortical based and isointense with gray matter on unenhanced T1-weighted images and mildly hyperintense on T2-weighted images (Figs. 1–5). One tumor was cortical based and hyperintense relative to gray matter on T1-weighted images (Fig. 6). Cystic components were seen in two patients (Figs. 5 and 6). Five of six masses were less than 3.5 cm in diameter. One patient had an infiltrative tumor involving the temporal lobe and basal ganglia (Fig. 4). Peritumoral edema was seen in only one patient (Fig. 2). Mass effect usually was not seen. All the masses enhanced with contrast material. The noncystic portions of the masses enhanced intensely. Four of the tumors were in the temporal lobes and two were in the parietal lobes. Surrounding leptomeningeal enhancement was seen in two patients (Figs. 1 and 6). Surrounding gyriform enhancement was seen in another patient (Fig. 4). Clinically, three patients had seizures and three had headaches.

Discussion

In 1973, Kepes et al. [1] described three cases of superficial temporal lobe tumors in young patients. Subsequently, Kepes

et al. [10] described superficial brain tumors in another 12 young patients. Pleomorphic xanthoastrocytoma was first described as a variant of cerebral astrocytomas with distinct clinical and pathologic features [10]. The tumor occurs primarily in children or young adults and affects males and females in equal numbers. Typically, patients have a long history of seizures. Pleomorphic xanthoastrocytoma differs from other cerebral astrocytomas by having a relatively favorable prognosis; postoperative survival of up to 25 years has been reported [11]. Occasionally, malignant conversion has been reported [4, 12].

The CT findings of this unique tumor have been described [2–9]. This well-marginated tumor is often hypodense or cystic. Diffuse or focal enhancement is seen with contrast material. Although these tumors frequently show intense contrast enhancement on CT images, findings on angiograms can vary from an avascular mass to an intense tumor stain [2–5]. One patient with pathologically proved pleomorphic xanthoastrocytoma was not included in our series because only preoperative CT images had been obtained. The large tumor was located in the left parietal lobe and was predominantly cystic with an isodense nodule that enhanced intensely with contrast material. These findings are similar to findings described in previous reports. In none of the six patients in

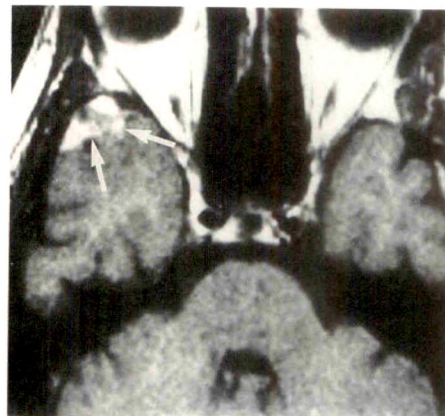
Fig. 3.—32-year-old man with pleomorphic xanthoastrocytoma who had seizures.

A, Axial T1-weighted (600/20/1) MR image shows small mass (arrows) isointense with brain in right temporal tip.

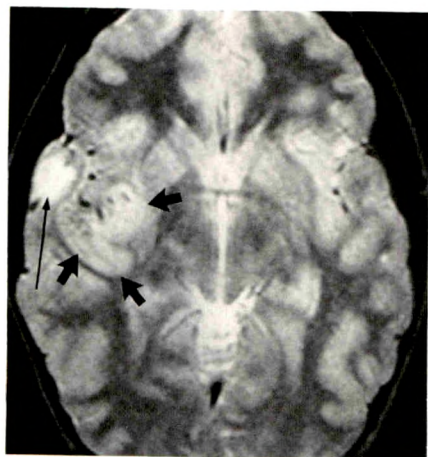
B, Axial T1-weighted (600/20/1) MR image with contrast material shows mass with patchy but intense enhancement (arrows).



A



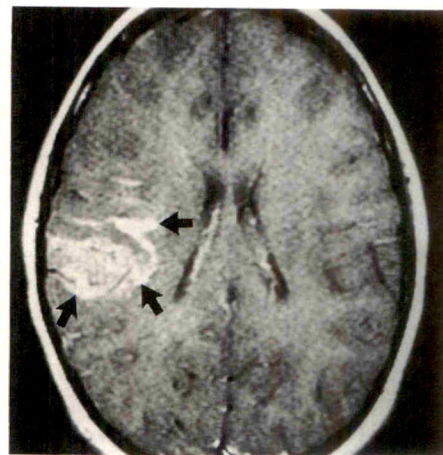
B



A



B



C

Fig. 4.—12-year-old girl with pleomorphic xanthoastrocytoma who had headaches.

A, T2-weighted (2800/80/1) MR image shows small area of abnormal high signal (long arrow) abutting right temporal cortex. Right insular cortex is also thickened (short arrows).

B, T2-weighted MR image obtained a few centimeters above level in A shows thickened insular cortex (arrows).

C, T1-weighted MR image with contrast material shows sulcal-gyriform enhancement of right upper temporal insular region (arrows).

our series were preoperative CT images available for analysis. The most common location of the mass is the temporal lobe; next, in order, are the parietal, occipital, and frontal lobes. Leptomeningeal enhancement and peritumoral edema have been reported [13]. Correlation of the imaging findings with histologic specimens would favor actual invasion or involvement of the meninges by tumor. We support the hypothesis that nonresected leptomeningeal invasion could account for tumor recurrence. Furthermore, peritumoral edema may be a poor prognostic factor for tumor recurrence and anaplastic evolution. The only patient with peritumoral edema (Fig. 2) in our series had a recurrence 4 months after resection of the left parietal mass.

In our patients, most tumors were isointense with gray matter on unenhanced T1-weighted MR images and hyperintense on T2-weighted images. These imaging characteristics are nonspecific. One tumor (Fig. 6) was hyperintense relative to gray matter on T1-weighted images. Histologic examination did not show any significant area of lipid, hemorrhage, or melanin within this tumor to account for the T1

shortening. Most likely, the T1 shortening seen on MR images of this tumor was caused by the calcification noted on histologic examination. Noncystic portions of the tumor usually enhance intensely with contrast material. Sulcal spread could be extensive (Fig. 4). In our series, cyst formation associated with pleomorphic xanthoastrocytoma (two of six patients) was not as common as has been reported. However, the common feature was that they were all cortical based without significant mass effect. The radiologic differential diagnosis of a cortical-based enhancing mass should include meningioma, oligodendroglioma, ganglioglioma, meningioangiomatosis, pleomorphic xanthoastrocytoma, hemangiopericytoma, lymphoproliferative mass, anaplastic astrocytoma, metastasis, inflammatory mass, and granulomatous disease (e.g., sarcoidosis, fungal disease).

On pathologic examination, pleomorphic xanthoastrocytoma is usually seen as a superficial temporal or parietal mass. Grossly, a yellowish cyst with a mural nodule is common, with the solid portion contacting the leptomeninges. The border of the lesion with the underlying brain is usually dis-

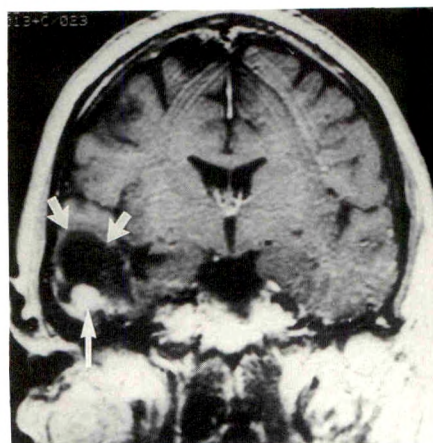
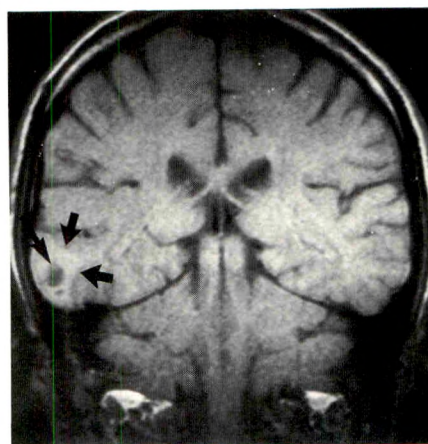
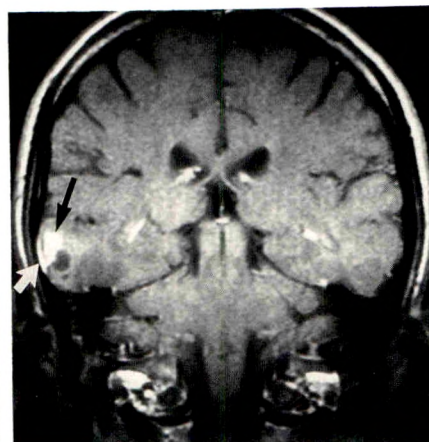


Fig. 5.—52-year-old woman with pleomorphic xanthoastrocytoma who had seizures. T1-weighted (600/20/1) MR image with contrast material shows a large cystic mass (short arrows) at right temporal tip and an intensely enhancing mural nodule (long arrow).



A



B

Fig. 6.—23-year-old man with pleomorphic xanthoastrocytoma who had headaches. A, Coronal T1-weighted (600/20/1) MR image shows a hyperintense mass (short arrows) in right lateral temporal cortex. Note low-signal cystic component (long arrow) in center of mass. B, T1-weighted MR image with contrast material shows part of mass enhances intensely (black arrow) with adjacent leptomeningeal enhancement (white arrow).

tinct, although an infiltrative appearance may also be present [10]. Fusiform cells arranged in a storiform pattern intermingling with areas of impressive pleomorphism are a key feature of these tumors. The classic microscopic features are (1) dense cellular areas with large, hyperchromatic, pleomorphic cells that may be multinucleated; (2) lipidization of astrocytes; (3) foci of perivascular lymphocytes; and (4) abundant reticulin network. Lipidization is an inconstant feature and may be difficult to show in some cases [14]. Necrosis was not found in these tumors, and mitoses were scant. Immunohistochemical techniques show the presence of glial fibrillary acidic protein in the tumor cells, distinguishing them from the cells of fibrous xanthoma, which histologically may closely resemble pleomorphic xanthoastrocytoma [10, 15]. Electron microscopy shows the presence of an uninterrupted basal lamina closely following the plasma membrane of the tumor cells [10, 16]. This feature is shared by subpial astrocytes, which has led to the suggestion that this is the cell of origin of pleomorphic xanthoastrocytoma [10].

In summary, pleomorphic xanthoastrocytoma is a rare, usually benign, cortical-based mass found most often in young patients. Seizures and headaches are the most common clinical features. These tumors usually enhance intensely on MR images with contrast material. However, the identification of peritumoral edema on MR images may suggest a more aggressive lesion. Familiarity with this tumor is important in the differential diagnosis of enhancing intracranial cortical-based masses.

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Calcification of the Trochlear Apparatus of the Orbit: CT Appearance and Association with Diabetes and Age

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Jon A. Spar¹
William W. Orrison, Jr.^{1,2}

OBJECTIVE. Calcification can sometimes be observed on CT scans in the region of the trochlear apparatus of the orbit, the cartilaginous structure through which the superior oblique tendon and its sheath pass. We evaluated associations of trochlear calcifications with age and diabetes.

MATERIALS AND METHODS. We retrospectively reviewed CT scans of the orbit in 159 patients to identify the presence of trochlear calcifications. The presence or absence of diabetes, duration of diabetes, type of therapy, and presence or absence of neuropathy were determined from medical charts of 139 patients. We calculated the odds ratio of detecting a trochlear calcification and used logistic regression to evaluate the associations of age, sex, and diabetes with trochlear calcification.

RESULTS. Trochlear calcifications were present in seven of the 24 diabetic patients and in 10 of the 115 nondiabetic patients. The odds ratio for detecting trochlear calcifications in diabetic vs nondiabetic patients was 4.3 ($p < .01$). Logistic regression showed univariate associations with trochlear calcification for both increasing age ($p < .001$) and diabetes mellitus ($p < .01$). The effect of diabetes on the prevalence of trochlear calcifications was seen predominantly in those less than 40 years old (odds ratio = 24.0, $p = .014$). Sex, duration of diabetes, insulin dependence, and neuropathy were not significantly associated with an increase in trochlear calcifications.

CONCLUSION. The results show that a trochlear calcification seen on CT is a benign condition that may serve as a marker for diabetes in young patients. Trochlear calcifications are observed frequently (25–30%) in persons more than 50 years old. When it is present in patients younger than 40 years, it is strongly associated with diabetes.

AJR 159:1291–1294, December 1992

High attenuation within the orbit on unenhanced CT scans can be caused by calcification or a foreign body. Distinction between these two causes can be important, particularly in patients for whom subsequent MR imaging is desired [1]. We investigated this finding after observing several cases of calcification in the region of the trochlear apparatus of the orbit, the cartilaginous structure through which the superior oblique tendon and its sheath pass. Because several such cases occurred in diabetic patients, we evaluated the possibility of an association between diabetes mellitus and trochlear calcification. CT scans and medical charts of 139 patients who underwent CT of the orbits were reviewed and CT findings in patients with trochlear calcifications are described.

Materials and Methods

We reviewed 159 CT scans of the orbit obtained at our institution during a 13-month period. The patients were from 8 months to 89 years old (mean, 39 years). Contiguous 3-mm axial sections were imaged without the use of IV contrast material. Some patients were imaged with direct coronal CT also. The studies were performed on a GE 9800 Quick scanner and a Technicare 1440 HPS scanner (General Electric Medical Systems, Milwaukee, WI).

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We reviewed all available medical charts of these patients for information on the presence or absence of diabetes mellitus and for the type of therapy, interval since diagnosis, and presence of neuropathy in diabetic patients. This information was available for 139 patients. In 16 patients, CT scans of the orbit had been obtained as part of an ongoing diabetes research project; 74 patients had a history of metalworking and were scanned to detect intraocular metal before MR imaging; 42 patients had acute orbital trauma; and seven patients had known or suspected tumor, infection, or vascular malformation involving the orbit. Of the 139 patients, 27 were female and 112 were male. The high percentage of males in this study is because metalworkers are predominantly male and because many trauma patients are young men. Among the 74 patients with a history of metalworking, the reasons they were referred for MR imaging varied and included evaluation of known or suspected intracranial disease (45), the spine (13), musculoskeletal conditions (nine), the aorta (one), and orbital tumor or suspected mass (four patients, none of whom had trochlear calcifications). We were unable to determine the reason for referral for two patients.

The odds ratio of detecting trochlear calcifications was calculated for diabetic vs nondiabetic patients. The relationship of trochlear calcification, age, and diabetes also was examined by using logistic regression. Statistical analysis was restricted to the 139 patients for whom both CT scans and a medical history were available.

Trochlear calcification was diagnosed when attenuation was high at the point of angulation of the superior oblique muscle (Figs. 1 and 2). Calcification in this location lies close to but not contiguous with the medial orbital wall. A typical appearance was seen on coronal views or coronal reconstruction (Fig. 3).

Results

Trochlear calcification was observed on the CT scans of 19 (12%) of 159 patients. Trochlear calcifications were bilateral and symmetric in eight, asymmetric in one, and unilateral in 10 patients. No patient had a clinical history of tendon sheath syndrome. Other results reported here are from the 139 patients for whom information on diabetes was included on their medical charts.

Twenty-four of the 139 patients had a history of diabetes mellitus (including the 16 from the research study). Fourteen were being treated with insulin, eight with oral agents, and two with diet control only. The intervals since the diagnosis

of diabetes ranged from 1 to 23 years. Time of onset for one patient was unclear from the medical chart. This patient was excluded from analysis of this factor. Fifteen of the 24 diabetic patients had evidence of neuropathy.

Seven (29%) of the 24 diabetic patients had trochlear calcifications, compared with 10 (9%) of 115 nondiabetic patients.

The mean age of the 139 patients was 39 years. The mean age of both diabetic and nondiabetic patients with trochlear calcifications was 52 years. Among those without trochlear calcifications, the mean age of diabetic patients was 52 years and the mean age of nondiabetic patients was 34 years. The age distribution of the patients is listed in Table 1.

The odds ratio of detecting trochlear calcification in the diabetic patients vs detecting it in nondiabetic patients is 4.3 ($p < .01$), with 95% confidence limits of 1.4–12.9. In other words, for the population studied and at a 95% confidence limit, the odds of a trochlear calcification in diabetic patients are between 1.4 and 12.9 times the odds of a trochlear calcification in the general population. However, this ratio does not take age into account. Logistic regression, therefore, was used to determine the effects of age, sex, and diabetes on the probability of trochlear calcification. Individually, age was highly significant ($p < .001$), as was diabetes ($p < .01$). No significant difference between the occurrence of trochlear calcifications in men and women was observed. Trochlear calcification was not identified in any of the patients examined for orbital neoplasm, infection, or vascular malformation.

We did see a relationship between diabetes and age in the association with trochlear calcifications. This was demonstrated when we separately examined patients less than 40 years old and those 40 years or older. For the younger group ($n = 81$), the odds ratio of trochlear calcification in diabetic vs nondiabetic patients was 24.0 ($p = .014$). For the older group ($n = 58$), the odds ratio was 1.7 (not statistically significant). The test for interaction of diabetes with age in relation to trochlear calcification when using logistic regression yielded $p = .067$.

Examination of the diabetic patients did not reveal a statistically significant association of insulin dependence, interval since diagnosis, or presence of neuropathy with the finding of trochlear calcification.

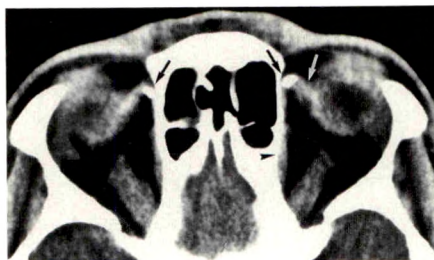


Fig. 1.—Axial CT scan of orbit shows bilateral trochlear calcifications (black arrows). Posterior (arrowhead) and anterior (white arrow) portions of superior oblique muscle are well seen.

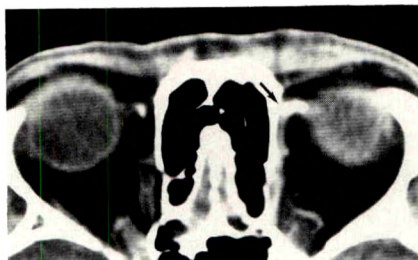


Fig. 2.—Axial CT scan through upper part of orbits shows unusually prominent calcification (arrow) in left orbit.



Fig. 3.—Direct coronal CT scan through anterior portion of orbits shows trochlear calcification (arrow) in right orbit.

TABLE 1: Age Distribution of Patients with Trochlear Calcifications

Age (yr)	No. of Patients with Trochlear Calcifications (Total)	
	Diabetic	Nondiabetic
0-9	0 (0)	0 (6)
10-19	0 (0)	0 (9)
20-29	1 (2)	0 (26)
30-39	1 (6)	1 (32)
40-49	1 (1)	4 (22)
50-59	1 (3)	2 (7)
60-69	2 (8)	2 (9)
70-79	1 (4)	0 (1)
80-89	0 (0)	1 (3)

Discussion

The occurrence of trochlear calcification has been mentioned by Mafee [2]. We have found no prior description of the typical CT appearance and location of this finding and no evaluation of possible associated medical conditions. We do not know the actual site of calcification in the region of the trochlear apparatus. Cartilage, the synovial sheath, and the tendon itself are all possible locations. The first two might be expected occasionally to cause a target or tram-track appearance, which we did not observe. However, pathologic correlation was not available.

The trochlear apparatus of the eye is a cartilaginous structure with a synovium-lined sheath [3] that permits unimpeded movement of the superior oblique muscle. The tendon of the superior oblique muscle passes through the trochlear apparatus as it makes a sharp lateral bend to insert on the superior lateral part of the globe. The causes of calcification in this location are unclear, but inflammatory, degenerative, and metabolic processes are all possibilities. Accurate discrimination between intraorbital calcifications and foreign bodies may be important for patients who will be examined with MR imaging. Blindness resulting from the movement of an intraocular foreign body during MR imaging has been reported, and the particle identified on an earlier CT scan was thought

to be calcification [1]. Attenuation values on CT are of limited use because of volume averaging. Although the appearance and location of trochlear calcification is quite distinctive, the possibility of a metallic foreign body cannot be excluded by these criteria alone (Fig. 4).

We observed an increase in trochlear calcifications with advancing age. Trochlear calcification was uncommon in patients less than 40 years old but was seen in one fourth to one third of patients 50 years old or older. This pattern is suggestive of a degenerative process, and in many cases the condition occurred in the absence of serious, chronic medical disease.

The association between diabetes mellitus and trochlear calcification was statistically significant only in those less than 40 years old, indicating an interaction between the effects of diabetes and age. Two of the three patients less than 40 years old who had trochlear calcifications were diabetic, and the third had only a tiny area of high attenuation. The statistical test of interaction between diabetes and age yielded a significance of $p = .067$. Failure to achieve significance at a .05 level may be due to the small sample size and the resulting limited statistical power.

Certain pathologic conditions can affect the trochlea. Brown's syndrome (tendon sheath syndrome) is a disorder of ocular motility with restriction of active and passive elevation of the globe in adduction [4]. Causes include anomalies of the superior oblique tendon and its sheath, inflammatory conditions, trauma, and postsurgical changes. A clicking sensation in the area of the trochlea may be reported, and sometimes acute inflammation is characterized by pain and tenderness in the trochlear region. Acquired Brown's syndrome can be an unusual complication of rheumatoid arthritis [5]. Low signal intensity and a nodular appearance of the tendon have been reported on MR images of a patient with long-standing juvenile rheumatoid arthritis and Brown's syndrome [6]. Inflammation of the tendon and the tendon sheath lead to thickening of the superior oblique muscle and tendon, which has been observed on sonography and CT [7, 8]. We know of no reports of calcification in association with Brown's syndrome. Although chronic inflammation might be expected to cause calcification, inflammation of the trochlear apparatus

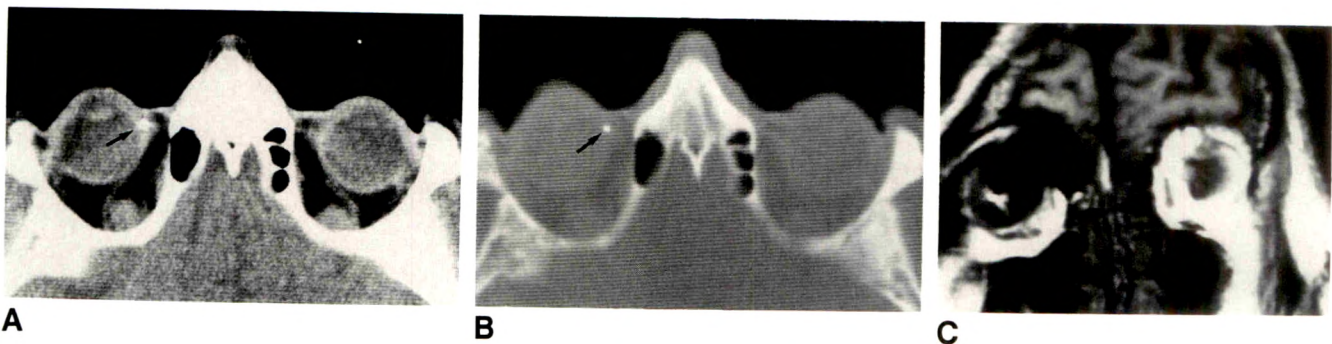


Fig. 4.—A, CT scan with soft-tissue windows shows “star artifact” of metallic foreign body in right orbit (arrow). B, CT scan shows metallic foreign body (arrow) with appearance similar to trochlear calcification in Figs. 1 and 2. C, Coronal MR image (700/15) shows signal void from metallic foreign body in right orbit that was initially interpreted as calcification on CT scans.

was not observed as an associated condition in any of the cases we reviewed.

We now consider the finding of trochlear calcification in patients less than 40 years old to be strongly suggestive of underlying diabetes. In the fifth decade of life, such calcifications occur more frequently in the general population. Trochlear calcification is fairly common (25–30%) in patients more than 50 years old. The frequency of trochlear calcifications in those more than 50 years old limits the significance of the observation in an individual patient.

In conclusion, trochlear calcification should be recognized as a benign condition with a characteristic location and configuration on CT scans. In younger patients, it may be a marker of diabetes mellitus.

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Do Abnormalities of the Frontonasal Duct Cause Frontal Sinusitis? A CT Study in 198 Patients

Bertrand Duvoisin¹
Pierre Schnyder

OBJECTIVE. The purpose of the study was to determine the correlation between frontonasal duct abnormalities (narrowing or obstruction caused by hypertrophic mucosa) and frontal sinusitis. This study was based on the hypothesis that abnormalities of the frontonasal duct cause frontal sinusitis by impairing normal drainage of the sinus.

MATERIALS AND METHODS. CT studies of 198 consecutive patients with clinical diagnoses of chronic sinusitis were reviewed retrospectively. Criteria for inclusion were (1) no history of sinus surgery or facial trauma and (2) absence of polyps at rhinoscopy. As 37 frontal sinuses were undeveloped, a total of 359 sinuses were evaluated. CT scans were obtained in oblique axial and coronal planes. The following CT features were assessed: (1) the frequency of detection of the frontonasal duct, (2) the appearance of the frontonasal duct: normal vs abnormal (narrowed or obstructed), and (3) the correlations between abnormalities of the frontonasal duct and frontal sinusitis.

RESULTS. The frontonasal duct was detected in all 359 cases, either in both CT planes (81%) or only in the axial oblique plane (19%). In 267 (74%) of 359 cases, the duct appeared normal; among these, isolated frontal sinusitis was detected in five cases (2%). In 92 (26%) of 359 cases, the duct was abnormal; it was narrowed in 18 cases (5%) and obstructed in 74 cases (21%). Frontal sinusitis was noted in 78 (85%) of the 92 cases of frontonasal duct abnormalities. The sensitivity and specificity of the correlations between frontonasal duct abnormalities and frontal sinusitis were 98% and 85%, respectively.

CONCLUSION. Because our results show a strong correlation between abnormalities of the frontonasal duct and frontal sinusitis, it seems highly probable that abnormalities of the frontonasal duct cause frontal sinusitis.

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In patients with chronic sinusitis, CT is needed to show the drainage pathways of the paranasal sinuses [1, 2]. To the best of our knowledge, specific CT analysis of the drainage pathway of the frontal sinus, also called the frontonasal duct, has not been reported.

We postulated that, in patients with chronic sinusitis, abnormalities of the frontonasal duct cause frontal sinusitis. Abnormalities of the frontonasal duct are not congenital variations, but inflammatory lesions. Hypertrophic mucosa causes narrowing or obstruction of the frontonasal duct, with subsequent impairment of the drainage of the frontal sinus. Thus, when frontal sinusitis is detected by CT, the frontonasal duct also should be examined with CT. In this study, we (1) assess the frequency of CT detection of the frontonasal duct in patients with chronic sinusitis, (2) analyze the appearance of the frontonasal duct, and (3) correlate the appearance of the frontonasal duct with that of the frontal sinus.

Materials and Methods

CT studies of 198 consecutive patients (74 males and 124 females), from 10 to 83 years

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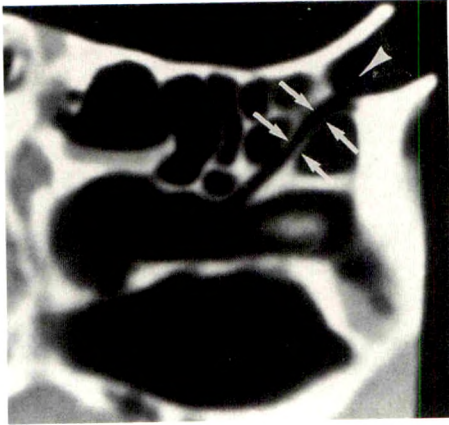


Fig. 1.—Sagittal CT scan of specimen of head shows obliquity and tilting of frontonasal duct (arrows) and origin of duct (arrowhead) at posteroinferior aspect of frontal sinus.

old (mean, 39 years), with chronic sinusitis were reviewed retrospectively. All examinations were done during a 2-year period, between January 1990 and December 1991. Chronic sinusitis was diagnosed clinically on the basis of a history of mucopurulent nasal discharge. As sinus surgery or facial trauma can alter the frontonasal duct, thus impeding its detection and analysis, patients with such a clinical history were not included in this study. Furthermore, patients with nasosinus polyposis were excluded, as analysis of their sinus

drainage pathways is unreliable because of the characteristic distortion and demineralization of their bony structures. In our series of 198 patients (396 frontal sinuses), we found 37 undeveloped frontal sinuses (9%). Evaluation of the frontonasal duct, and correlation of its appearance with that of the frontal sinus, was thus feasible for 359 frontal sinuses.

All CT examinations were performed with a CT Pace unit (General Electric Medical Systems, Milwaukee, WI), according to a protocol including oblique sections in the axial and coronal plane, without IV contrast material. The obliquity of the sections was determined by the axis of the frontonasal duct, which is tilted approximately 50° relative to the canthomeatal line. This angle of the frontonasal duct was established previously on lateral radiographs of cadaveric heads, after opacification of the duct by a metallic probe introduced via the frontal sinus [3], and was also confirmed on sagittal CT scans of the specimen (Fig. 1). The sections obtained are perpendicular and parallel to the frontonasal duct, in the axial oblique plane and the coronal oblique plane, respectively. Two-millimeter-thick slices are obtained with 2-mm intervals through the whole sinus region in the axial oblique plane, and contiguous 2-mm-thick sections are centered on the anterior ethmoidal sinus in the coronal oblique plane. In the first 70 patients, routine milliampere-second settings (390 mAs) were used, whereas in 128 patients, low-dose CT was performed, as described elsewhere [4]. All sections were photographed with a large window width (2000 H).

All CT examinations were analyzed retrospectively by one of the authors. The only available information was that the patient had chronic sinusitis. No correlations were made with treatment or the patient's outcome, as the study relied essentially on morphologic

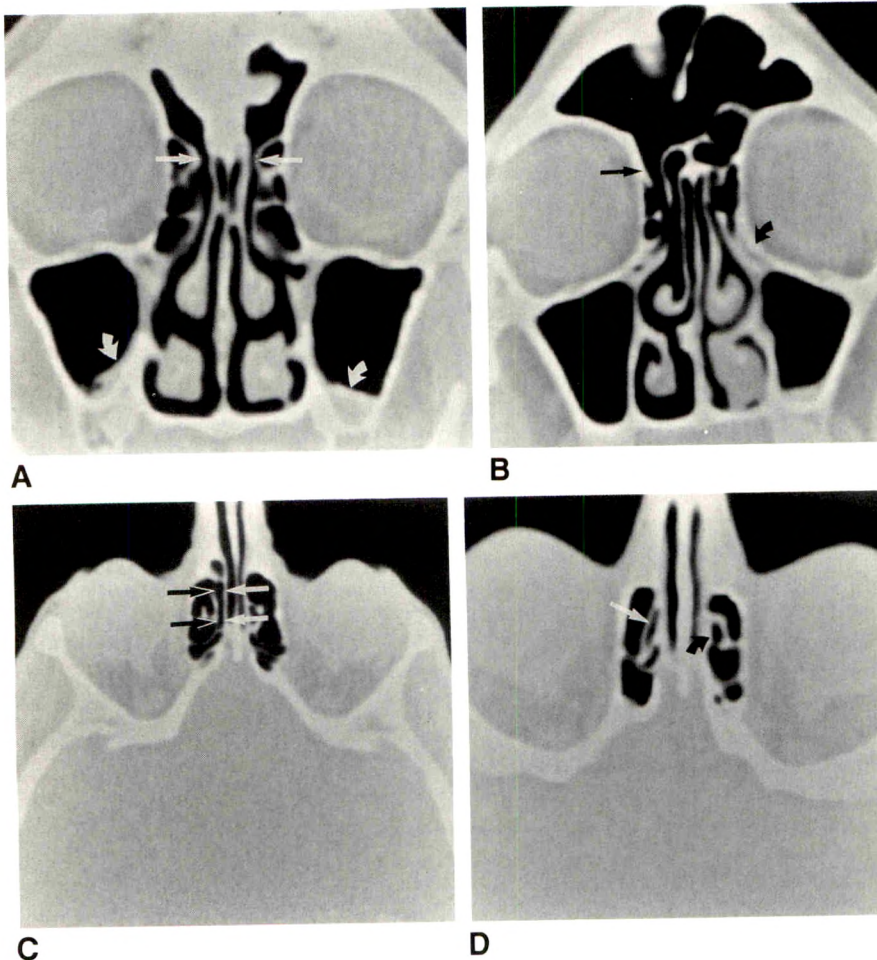


Fig. 2.—Normal frontonasal duct in different patients.

A, Coronal oblique CT scan shows medially situated frontonasal duct (straight arrows) on both sides. Note inflammation in both maxillary sinuses and small effusions (curved arrows).

B, Coronal oblique CT scan in another patient shows lateral location of right frontonasal duct (straight arrow). Note obstruction of left maxillary drainage way, due to inflammation of left ostiomeatal complex (curved arrow).

C, Axial oblique CT scan shows cleftlike right frontonasal duct (arrows).

D, Axial oblique CT scan shows fusiform right frontonasal duct (straight arrow) and round left frontonasal duct (curved arrow).

findings. The following CT criteria were assessed: (1) detection of the frontonasal duct, (2) appearance of the frontonasal duct: normal vs abnormal (i.e., narrowed or obstructed by hypertrophic mucosa), (3) appearance of the frontal sinus: normal vs abnormal (i.e., with hypertrophic mucosa and/or fluid), and (4) correlations between the appearances of the frontonasal duct (classified as either normal or abnormal) and the frontal sinus. For clinical reasons and statistical purposes (to diminish the number of classifications), narrowed and obstructed frontonasal ducts were combined into the abnormal group. Sensitivity and specificity of the correlations were determined, and the 95% confidence interval (95% CI) was calculated. The 95% CI was based on data relative to sinuses rather than to patients; actually, as there is no anatomic communication between right and left sinuses, correlations between frontonasal duct and frontal sinus are strictly homolateral.

Results

Among the 359 developed frontal sinuses, the frontonasal duct was visible on both axial oblique and coronal oblique CT scans in 289 cases (81%), whereas it was recognized only on the axial oblique CT scan in 70 cases (19%). In 337 cases (94%), the duct was medial (Fig. 2A), and in 22 cases (6%) it was lateral (Fig. 2B). In 320 cases (89%), the frontonasal duct appeared as a cleftlike (Fig. 2C) or fusiform (Fig. 2D) canal in the axial oblique plane, and in 39 cases (11%), it was more or less round (Fig. 2D).

The CT correlations between the appearance of the frontonasal duct and that of the frontal sinus are summarized in Table 1. The frontonasal duct appeared normal in 267 cases (74%). In five of these cases (2%), CT showed chronic frontal sinusitis, which consisted in slight hypertrophy of the frontal sinus mucosa; these five cases were considered false-negative. In 92 cases (26%), the frontonasal duct showed abnormalities, with narrowing by hypertrophic mucosa (Fig. 3) in 18 cases (5%), and obstruction (Fig. 4) in 74 cases (21%). Among these 92 cases, frontal sinusitis was noted on CT in 78 cases (85%), whereas the frontal sinus appeared normal in 14 cases (15%), which were considered false-positive.

When the false-negative and false-positive cases are grouped, the sensitivity and specificity of the correlations between appearance of the frontonasal duct and appearance of the frontal sinus are 98% (95% CI: 96–100%) and 85% (95% CI: 78–92%), respectively.

TABLE 1: CT Correlations Between Appearances of Frontonasal Duct and Frontal Sinus

Frontal Sinus	No. (%) of Frontonasal Ducts		
	Normal (n = 267)	Narrow (n = 18)	Obstructed (n = 74)
Normal Sinusitis	262 (98)	7 (39)	7 (10)
	5 (2)	11 (61)	67 (90)

Discussion

Recent developments in functional endoscopic sinonasal surgery have markedly increased the use of CT in the pre-surgical workup of chronic sinusitis [1, 2, 5, 6]. CT is needed to assess the extent of the sinus abnormalities and to examine the drainage pathways, among which the ostiomeatal complex is a key area. The anatomy of the ostiomeatal complex and its importance in the pathogenesis of chronic sinusitis have already been well documented [1, 2, 5, 6]. On the contrary, the CT anatomy of the drainage pathway of the frontal sinus and the correlation between the appearance of this structure and that of the frontal sinus have not been studied. Recently, a CT study of the relationship between frontal sinus drainage and ostiomeatal complex disease was reported [7]. The authors reported that 72% of cases with involvement of the ostiomeatal complex did not have frontal sinus disease and concluded that this finding was associated with a separate drainage of the frontal sinus, which was thus spared in maxillary or ethmoidal sinusitis.

The exact drainage system of the frontal sinus depends on its embryologic development. The drainage usually occurs directly into the frontal recess [8] or, by way of rudimentary anterior ethmoidal cells, into the frontal recess [8, 9]. The frontal recess is a deep anterosuperior depression in the middle meatus, which forms a closed channel in its upper surface, named the frontonasal duct [8–10]. Usually, the frontonasal duct runs medially across the anterior ethmoidal sinus, and rarely it runs laterally [9]. The frontonasal duct extends from the posteromedial portion of the sinus floor and runs caudally through the anterior ethmoidal labyrinth to its orifice in the nasal cavity [8–10]. The inferior aspect of the frontonasal duct is a component of the ostiomeatal complex

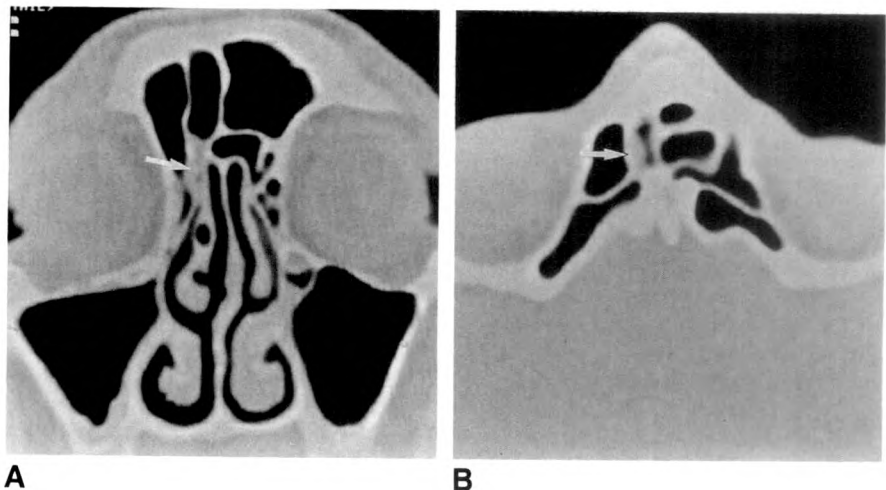


Fig. 3.—Reduced diameter of right frontonasal duct due to hypertrophic mucosa.

A. Coronal oblique CT scan shows right frontonasal duct (arrow) as almost obstructed.

B. Axial oblique CT scan shows partial patency of right frontonasal duct (arrow).

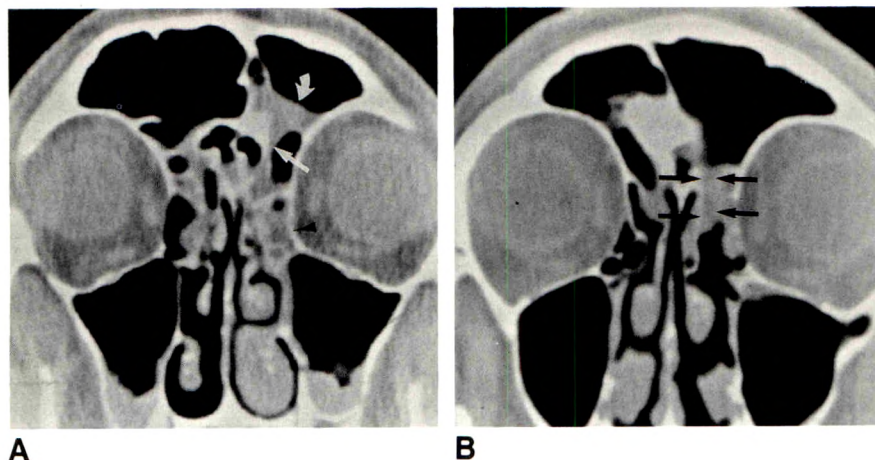


Fig. 4.—Obstruction of frontonasal duct in two different patients.

A, Coronal oblique CT scan in patient with frontal sinusitis shows obstruction of frontonasal duct (straight arrow) and frontal effusion (curved arrow). Note extensive inflammation of left ostiomeatal complex (arrowhead).

B, Coronal oblique CT scan in patient without frontal sinusitis shows obstruction of left frontonasal duct (arrows), but normal aeration of frontal sinus.

[6, 7]. Thus it can be affected by disease in this key anatomic zone, with possible subsequent disease of the frontal sinus. Recent papers have reported that abnormalities of the ostiomeatal complex are associated with frontal sinus disease in 27–39% of cases [1, 7].

No reports mention any statistical study dealing with the CT visibility, route, or appearance of the frontonasal duct. This is probably because the plane used in routine coronal CT is not suitable for analyzing the frontonasal duct, which is tilted approximately 50° relative to the canthomeatal line [3]. CT identification of the frontonasal duct was initially achieved on cadaveric heads, with endoscopic and macroscopic correlations (Duvoisin B et al., presented at the Radiological Society of North America meeting, December 1988). In vivo CT studies were then correlated with endoscopic findings, confirming the specimen data on frontonasal duct identification (Duvoisin B, unpublished data). The route and morphology of the frontonasal duct vary among subjects. In our series, in most cases (94%), the duct crosses the medial aspect of the anterior ethmoidal sinus. Usually, the frontonasal duct has an ovoid or cleftlike appearance on oblique axial slices (89%). In 11% of cases, its shape is roughly circular.

The results of this retrospective study show that the frontonasal duct is consistently depicted on axial oblique and coronal oblique CT scans. It was well recognized on both axial oblique and coronal oblique scans in 289 cases (81%) and only on the axial oblique scan in the other 70 cases (19%). For these 70 cases, we postulate that the lack of visibility of the frontonasal duct in the coronal oblique plane is due either to partial volume effects or to an unusual anatomic tilting of the duct relative to the canthomeatal line.

In 267 cases (74%), the frontonasal duct was normal. Associated frontal sinus abnormalities were detected in only five cases (2%). In all five cases these abnormalities consisted in slight hypertrophy of the mucosa of the frontal sinus; this was considered to have been caused by an earlier case of frontal sinusitis, which could have been associated with a previous, now cured, inflammatory narrowing of the frontonasal duct.

In 92 cases the frontonasal duct showed chronic inflammatory changes, with hypertrophic mucosa narrowing ($n = 18$) or obstructing ($n = 74$) the frontonasal duct. Associated frontal sinusitis was observed in 78 cases (85%). Thus,

frontonasal duct abnormalities, which impair drainage of the frontal sinus, are significantly associated with frontal sinusitis. These data show a high correlation between frontonasal duct abnormalities and frontal sinusitis, which is illustrated by a sensitivity of 98% (95% CI: 96–100%) and a specificity of 85% (95% CI: 78–92%).

In all cases (100%) in which the frontonasal duct was abnormal, disease of the ostiomeatal complex was noted. As in our series, abnormalities of the frontonasal duct are usually associated with CT signs of frontal sinusitis (85%); our results differ significantly from published studies, which report 39% and 27% prevalences of frontal sinus disease in cases of ostiomeatal complex abnormalities [6, 7]. The hypothesis of a separate drainage of the frontal sinus, evoked by others [7], thus seems debatable.

In conclusion, we recommend careful examination of the frontonasal duct on CT scans of patients with chronic sinusitis, because duct abnormalities seem to correlate strongly with frontal sinusitis.

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Pictorial Essay

Venous Angioma of the Brain: History, Significance, and Imaging Findings

Charles L. Truwit¹

Venous angioma of the brain consists of multiple, radially oriented dilated medullary veins that drain into a parenchymal venous stem. Although early reports, especially those published before the advent of CT and MR, suggested that venous angioma is a rare lesion, it is probably the most common anomaly of the intracranial vasculature [1-3]. Most early reports [4, 5], and more recent papers [6], have suggested that patients with venous angioma, like patients with other vascular malformations, are at considerable risk for parenchymal intracranial hemorrhage. Today, however, most investigators [7-14] maintain that venous angioma of the brain is an incidental finding of little clinical relevance, and only rarely is it associated with complications, such as hemorrhage. This paper reviews the history and significance of venous angioma of the brain and presents the radiologic features.

History

Radiologic reports of this lesion date back to 1967, when Wolf et al. [15] described an unusual case of multiple venous angiomas in a patient who later died of intracranial hemorrhage from one of the lesions. That report has often been mentioned as the first angiographic description of this tumor in a living patient. Probably more relevant, however, is that the report by Wolf et al. was only the 10th pathologic report of a patient with intracranial hemorrhage due to a venous angioma. Although Wolf et al. clearly state in their opening sentence that venous angiomas are associated with hemorrhage only infrequently, many authors have (remarkably) as-

serted the contrary, a "fact" that cannot be supported by the MR experience. More remarkable, however, is the near absence of significant reports of the incidental nature of venous angiomas. In fact, only one longitudinal study of their benign nature has been published [7]. In addition, earlier reports [16] suggested that venous angiomas in the posterior fossa are more likely to hemorrhage than are their supratentorial counterparts. Both the small numbers of cases reported and the fact that complicated venous angiomas are the type reported, however, make suspect the conclusion of higher rates of hemorrhage in the posterior fossa. Thus, the early reports of hemorrhagic complications associated with venous angioma, compounded with the lack of reports on its incidental nature, suggest that it is an uncommon lesion with a high propensity for complication. Today, few neuroradiologists would subscribe to such a view. Venous angiomas are seen every few weeks to months by radiologists who interpret MR scans of the brain, and they are so common that they are mentioned only incidentally in case dictations. Very few patients with this lesion ever have intracranial hemorrhage.

In the last few years, greater numbers of venous angiomas have been identified [7-14, 17-23]. Recognition of the relatively benign nature of this lesion has permitted study of its natural history, raising serious questions about its potential to bleed primarily [7]. Moreover, several authors [24-26] have reported the association of cryptic vascular malformations and venous angiomas; the former are responsible for hemorrhage. Other investigators (Dillon WP et al., presented at the American Society of Neuroradiology meeting, June 1991)

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The opinions expressed herein are those of the author and do not necessarily reflect the opinions of the Department of the Army or Department of Defense.

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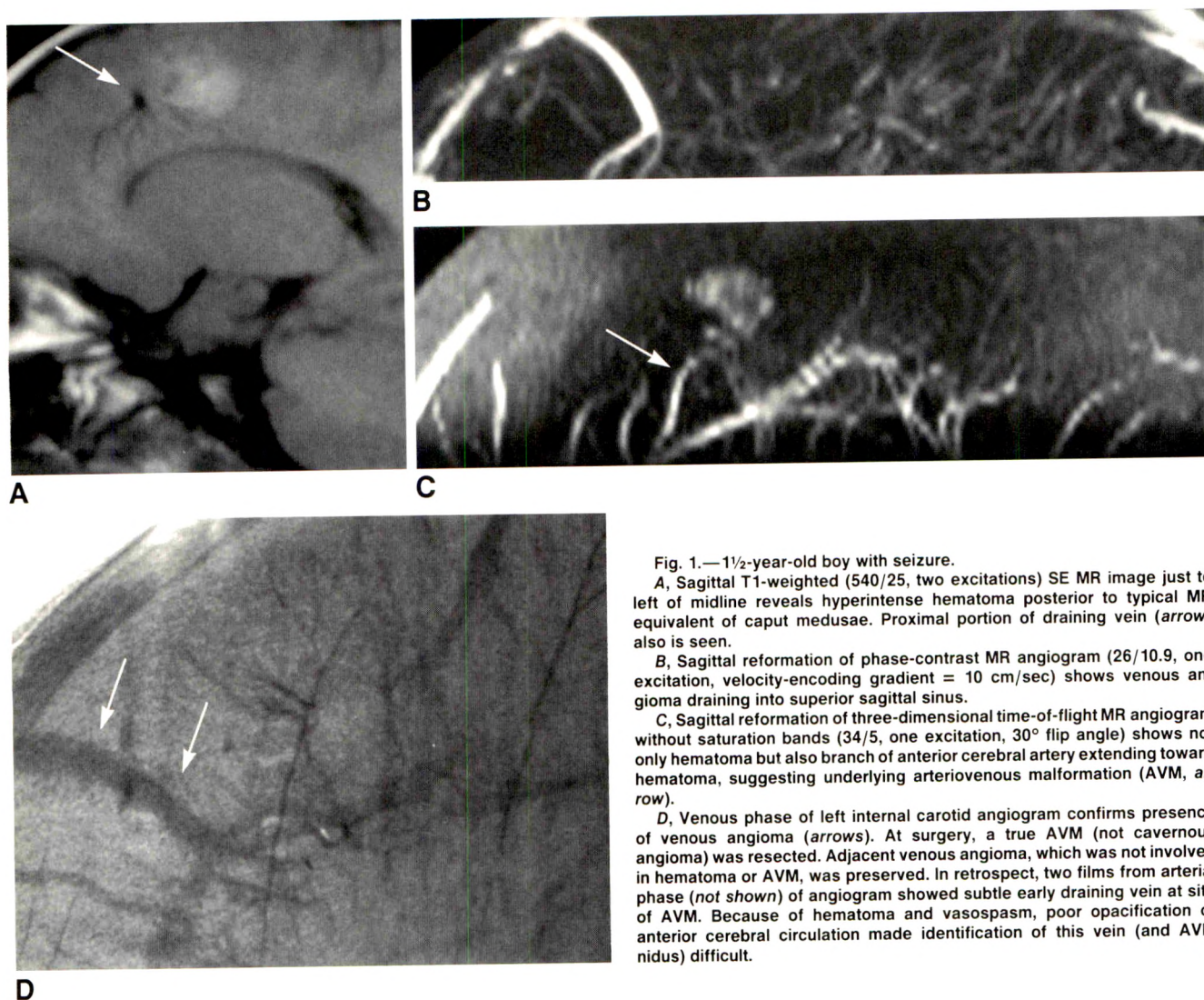


Fig. 1.—1½-year-old boy with seizure.

A, Sagittal T1-weighted (540/25, two excitations) SE MR image just to left of midline reveals hyperintense hematoma posterior to typical MR equivalent of caput medusae. Proximal portion of draining vein (arrow) also is seen.

B, Sagittal reformation of phase-contrast MR angiogram (26/10.9, one excitation, velocity-encoding gradient = 10 cm/sec) shows venous angioma draining into superior sagittal sinus.

C, Sagittal reformation of three-dimensional time-of-flight MR angiogram without saturation bands (34/5, one excitation, 30° flip angle) shows not only hematoma but also branch of anterior cerebral artery extending toward hematoma, suggesting underlying arteriovenous malformation (AVM, arrow).

D, Venous phase of left internal carotid angiogram confirms presence of venous angioma (arrows). At surgery, a true AVM (not cavernous angioma) was resected. Adjacent venous angioma, which was not involved in hematoma or AVM, was preserved. In retrospect, two films from arterial phase (not shown) of angiogram showed subtle early draining vein at site of AVM. Because of hematoma and vasospasm, poor opacification of anterior cerebral circulation made identification of this vein (and AVM nidus) difficult.

have suggested that venous angiomas in patients with acquired venous restrictive disease may be the ones that tend to hemorrhage. More recently, anecdotal evidence suggests that some of the "cryptic" vascular malformations suspected in cases of complicated venous angioma may in fact be true arteriovenous malformations (Edwards MSB, personal communication) (Fig. 1).

In summary, venous angioma has long been considered an uncommon abnormality of the intracranial venous system. Moreover, as noted by Scotti et al. [27], early reports suggested that this lesion is more common in the spinal cord than in the brain. Today, most radiologists would dispute this and would agree that venous angioma is probably the most common abnormality of the intracranial venous system and is a benign developmental venous anomaly in most cases.

Development

Like the epidemiology and clinical signs and symptoms, the embryologic development of venous angioma is not well

understood. A prevailing developmental concept [10, 11] suggests that these lesions represent an arrest of venous development, after arterial development is nearly complete. Such an arrest presumably results in the retention of primitive, embryologic medullary veins that drain into a single, large draining vein, the venous angioma. As such a vascular accident would take place after arterial definition, no abnormal arteries would be seen in most cases. This theory, however, implies an extremely focal arrest, as the surrounding brain parenchyma is reportedly normal in most patients with this abnormality. Although venous development is probably somehow focally arrested, venous angioma may be near the end of a spectrum of potential anomalies that can occur at various embryologic periods. Such a developmental scheme would permit the occasional associations seen with venous angioma, both vascular and parenchymal.

Although not commonly reported, infrequently associated with venous angioma are focal anomalies of neuronal migration (Fig. 2). While the case shown in Figure 2 is a particularly dramatic example of venous angioma and associated anomaly

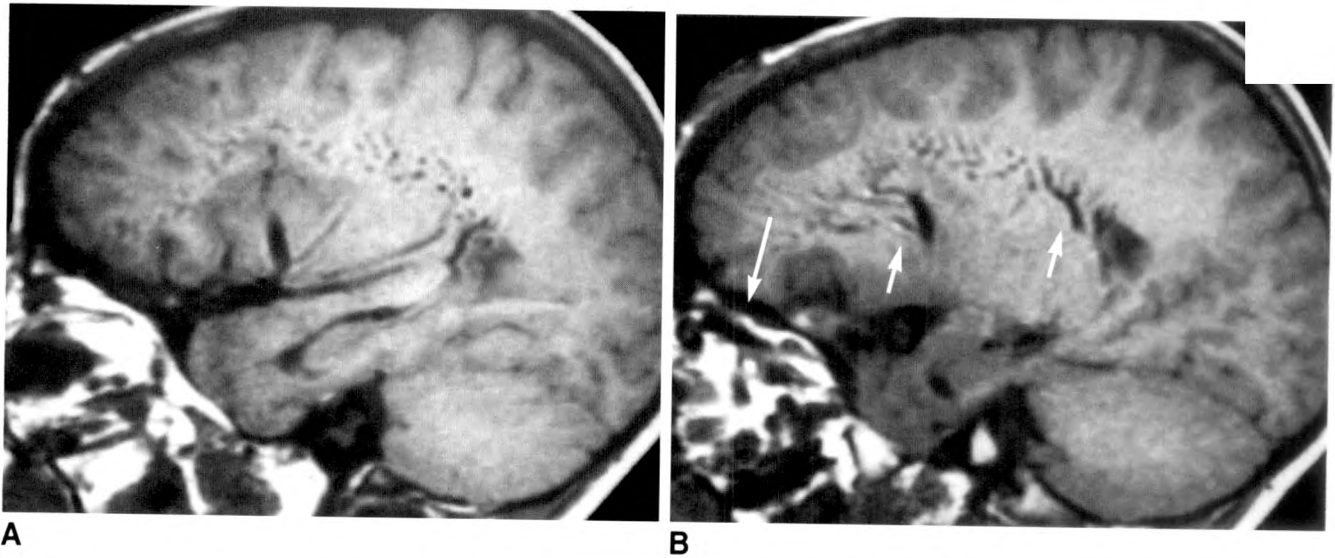


Fig. 2.—7-year-old boy with blue rubber bleb nevus.

A and B, Sagittal T1-weighted (600/30, one excitation) MR images show dramatic vascular malformation extending through entire left cerebral hemisphere. At least two enlarged draining veins are seen (*short arrows*). Note enlarged superior ophthalmic vein (*long arrow*) and extra flow voids within left orbit. Such transorbital extension is atypical of intracranial venous anomalies.

C and D, Axial proton density-weighted (2800/30, one excitation) MR images show characteristic spatial misregistration artifacts associated with venous flow. In this case, artifacts are associated with dilated medullary veins and multiple draining veins. Also note diffuse anomaly of neuronal migration involving left frontal and temporal lobes (*arrows*). Angiograms (*not shown*) depicted venous malformation consisting of multiple venous angiomas. No arterial abnormalities were detected.

(Case courtesy of W. Kelly, Fairfield, CA.)

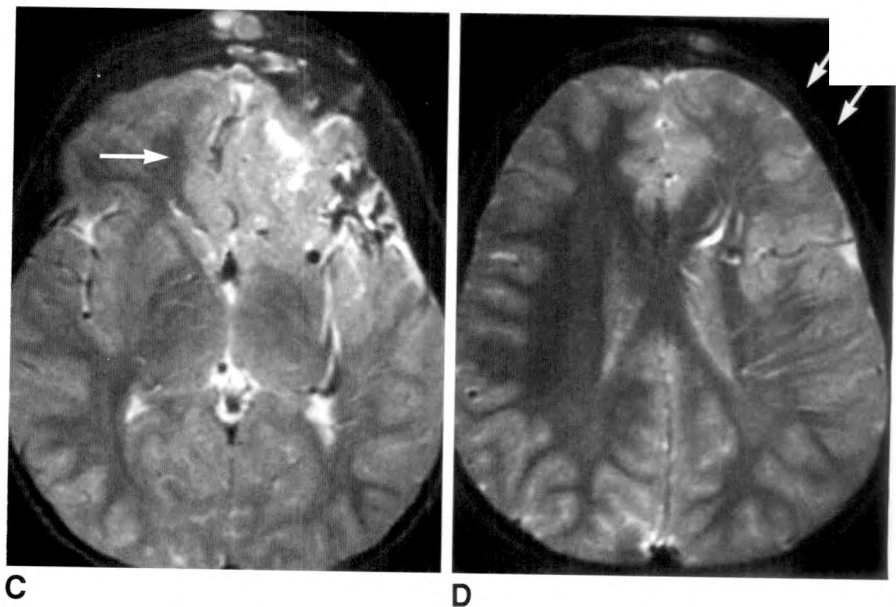
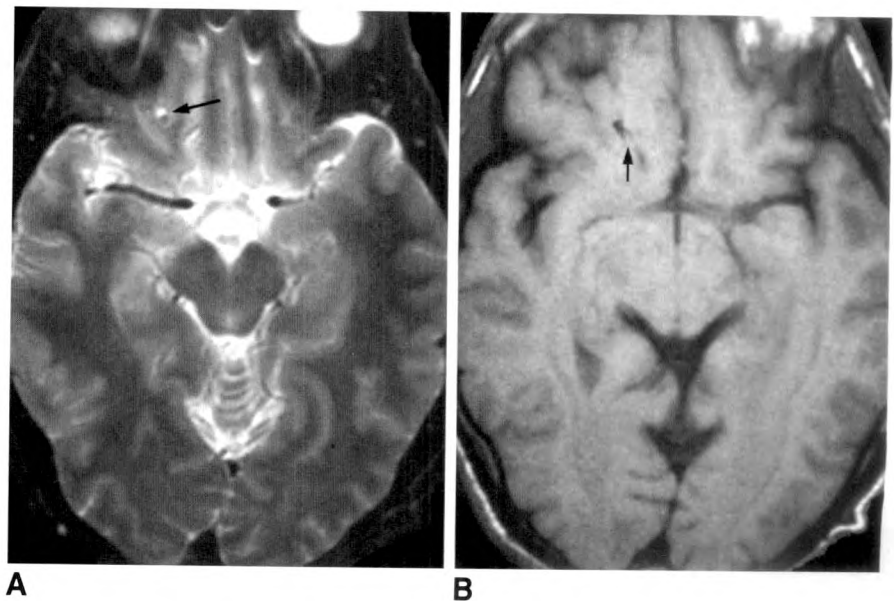


Fig. 3.—A, Axial T2-weighted (2900/90, one excitation) MR image shows subtle focus of abnormal signal in right inferior frontal pole. Note subtle spatial misregistration artifact (*arrow*) indicating flow.

B, Axial T1-weighted (600/20, two excitations) MR image also shows subtle venous angioma. Very short medullary veins (*arrow*) can be seen draining into very short draining vein. Contrast medium was not used in this case, but would have shown incidentally discovered angioma better.



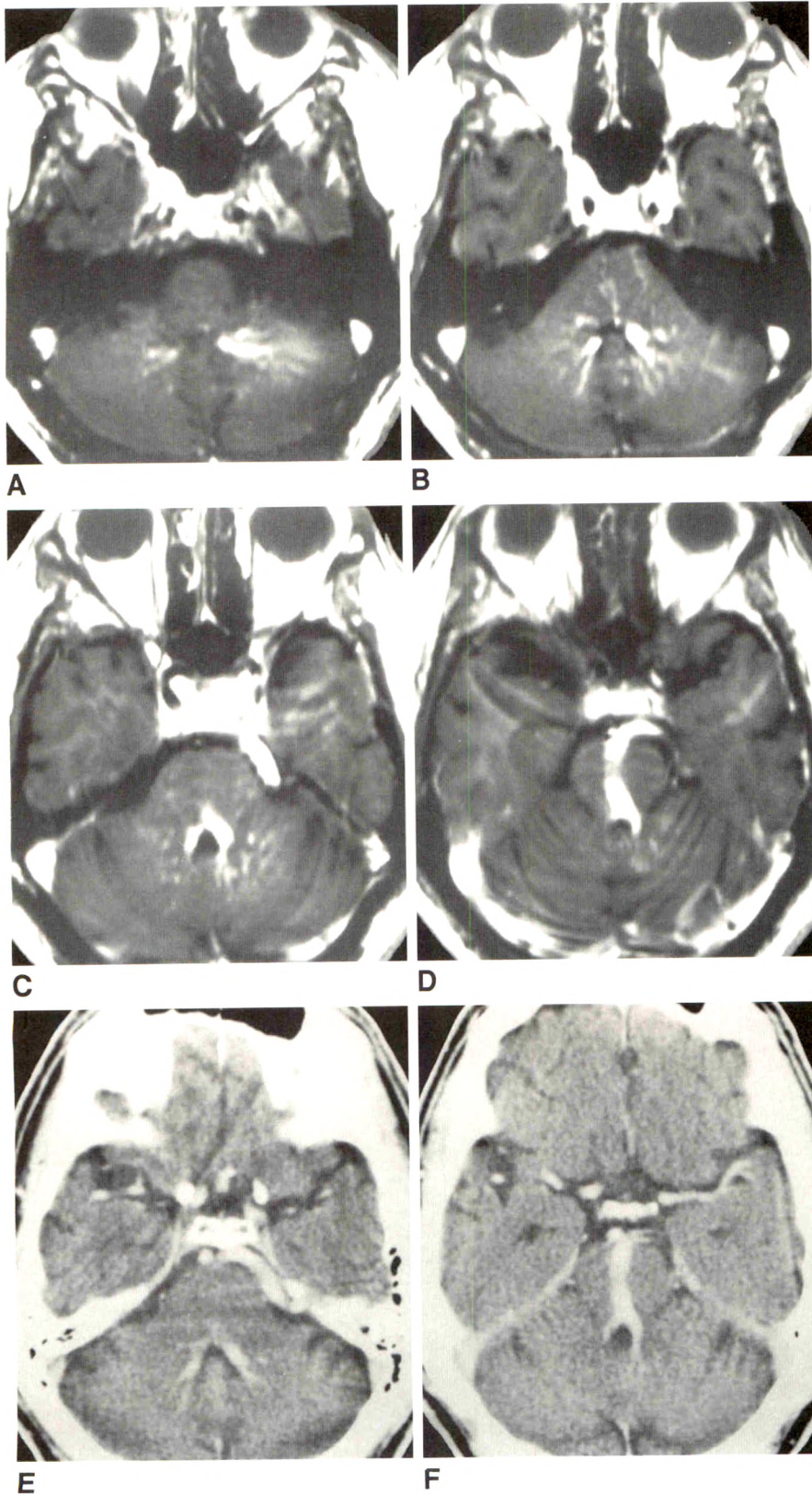


Fig. 4.—A–D, Contrast-enhanced axial T1-weighted (600/20, one excitation) MR images show transpontine draining vein and significant enhancement of medullary veins and parenchyma of left cerebellar hemisphere. Last finding suggests possible venous restrictive component of draining vein. Note abrupt termination of draining vein at junction with superior petrosal sinus.

E and F, Contrast-enhanced axial CT scans through posterior fossa show typical enhancement of medullary veins draining bilateral cerebellar venous angiomas to floor of fourth ventricle. Slightly more cephalad, note large transpontine draining vein with typical cisternal course toward superior petrosal sinus.

(Case courtesy of D. Symonds, Denver, CO.)

of neuronal migration, more subtle cases have been noted (Barkovich AJ, personal communication). Moreover, in schizencephalies and polymicrogyric clefts, it is common to see associated enlarged, persistent embryonic veins. Although

such veins are not typically included under the description of venous angioma, because of the failure to identify the "caput medusae" appearance of the dilated medullary veins and the predominantly subarachnoid nature of the enlarged veins,

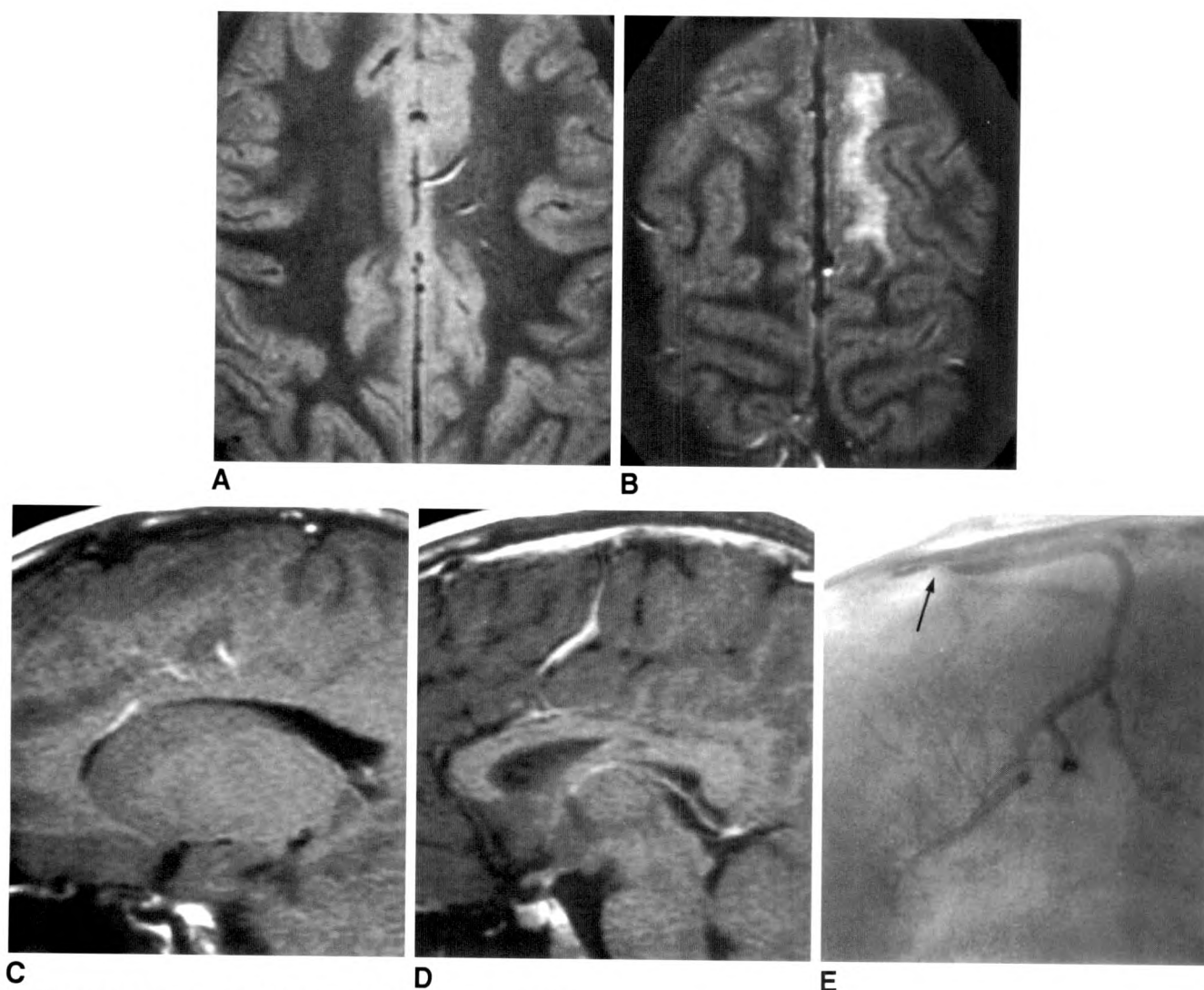


Fig. 5.—12-year-old boy with vague symptoms suggestive of seizure.
 A and B, Axial proton density-weighted (2500/30, one excitation) MR images show abnormal veins of corpus callosum and left centrum semiovale and hyperintensity of left frontal subcortical white matter. Abnormal signal suggested venous infarction.
 C and D, Contrast-enhanced sagittal T1-weighted (600/30, one excitation) MR images confirm venous malformation draining subependymal and callosal regions along medial aspect of left hemisphere. Few flow voids (*not shown*) raised question of arterial component.
 E, Late venous phase of left internal carotid arteriogram shows frontal venous angioma and tight stenosis of draining vein as it penetrates dura (*arrow*) to drain into superior sagittal sinus. Venous restrictive disease accounted for venous infarction.

such veins do fit the description of venous anomaly. Moreover, a recent report [28] of disturbed arterial and venous angioarchitecture in a patient with focal pachygyria supports the suggested occasional association of anomalies of venous development and neuronal migration. Thus, a possible embryologic basis for venous angioma would place them on the spectrum of focal developmental abnormalities with venous angioma and associated vascular anomalies such as arteriovenous malformation (AVM) or cryptic vascular malformation at one end, isolated venous angioma near that end, and venous angioma and associated anomaly of neuronal migration further toward the opposite end, and, finally, migration defect with associated venous anomaly at the far end. Such an approach would permit the many variations of venous anomalies of the intracranial vasculature.

Radiologic Appearances

Venous angiomas of the brain have many appearances, ranging from a small, single draining vein, involving at most one small portion of brain (Fig. 3) to a large hemispheric venous anomaly draining an entire hemisphere (Fig. 2). Venous angiomas can occur almost anywhere, but favored sites include the frontal lobes and the posterior fossa. They are typically unilateral, although bilateral ones have been reported, particularly in the posterior fossa [29] (Fig. 4). Venous angiomas are most frequently solitary, although it is not rare to find two or more of them immediately adjacent to one another. Supratentorial venous angiograms drain via trans-hemispheric channels, either to a superficial cortical vein (Fig. 5) or dural sinus or to the deep venous system, via a subep-

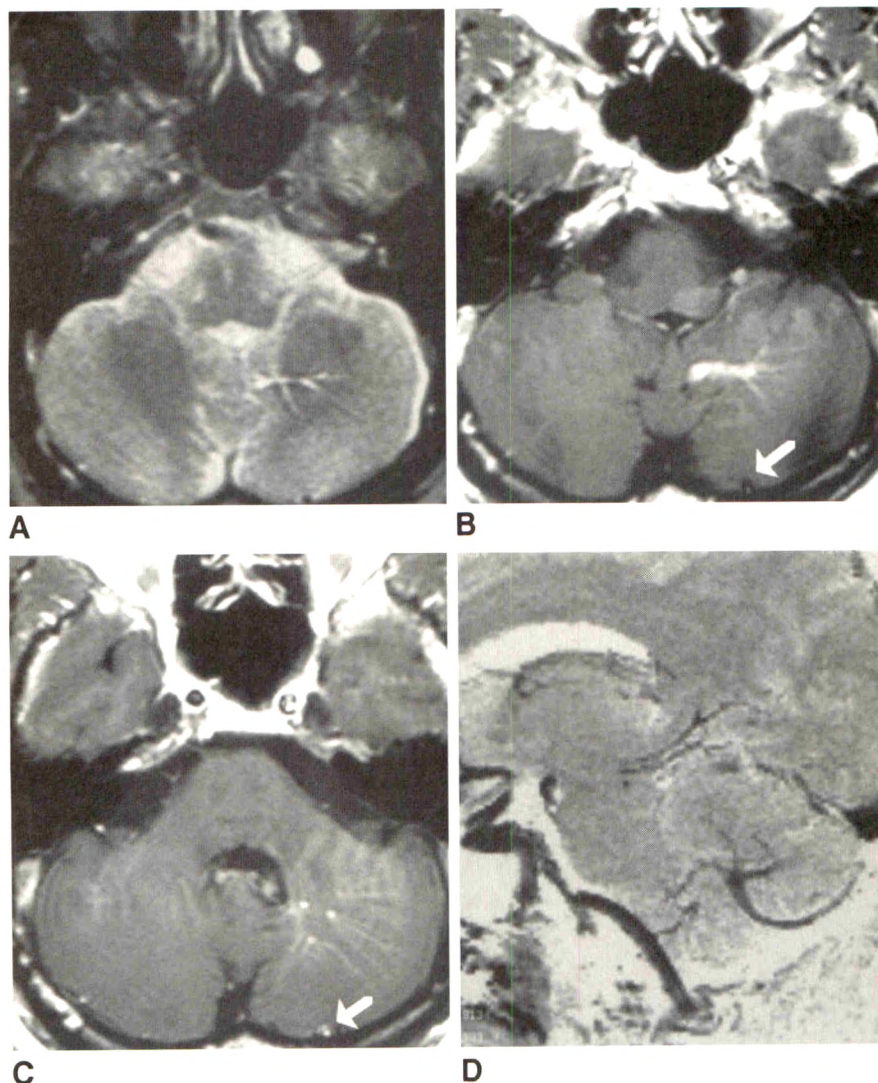


Fig. 6.—A, Axial T2-weighted (2800/80, one excitation) MR image shows venous angioma of left cerebellar hemisphere, few enlarged medullary veins, and draining vein.

B and C, Contrast-enhanced T1-weighted axial (600/20, one excitation) MR images show corresponding abnormality and prominent medullary veins. Draining vein loops beneath cerebellum (not shown) toward transverse sinus (arrows).

D, Sagittal reformation of three-dimensional time-of-flight MR angiogram clearly shows venous angioma and cisternal course back toward transverse sinus. Dilated medullary veins are still difficult to see on MR angiograms.

(Case courtesy of J. Sherman, Colorado Springs, CO.)

endymal vein. Occasionally, both routes of drainage are seen. Exceptionally, venous angiomas drain extradurally and transcranially via a sinus pericranii [9] (Fig. 2). In the posterior fossa, similar patterns of drainage are noted, including transparenchymal drainage to a superficial cerebellar vein (Fig. 6) or a dural sinus and deep drainage to the fourth ventricle, from where drainage occurs through the brainstem, through a peduncle, or through one of the fourth ventricular outlet foramina [26, 30].

In addition, venous angiomas are occasionally noted in the striatum (gray matter) [31] (Fig. 7) or, exceptionally, in the ventricular system [32, 33]. In ventricular venous angiomas, a typical caput medusae may not be apparent, and obstructive hydrocephalus due to the enlarged venous stem has been reported (Fig. 8).

Cavernous angiomas have been noted in association with venous angiomas in the posterior fossa [24, 25] and probably occur in the supratentorial compartment as well. Moreover, Dillon et al. (ASNR meeting, June 1991) recently suggested a causal relationship between venous restrictive disease and venous angiomas with associated cryptic vascular malfor-

mations in five patients. Associated arteriovenous malformation appears to be rare [7, 30], although this, too, has come under question, as noted earlier. Venous varix is infrequently seen in association with venous angioma [34], although varix might be expected to be more common if acquired venous restriction does play a significant role in complicated venous angioma.

Angiography

The most common angiographic descriptions of venous angioma include a caput medusae appearance of deep, medullary veins during the early to middle venous phase, accompanied by a single large draining vein, most often extending transhemispherically to a superficial cortical vein or dural sinus. Uncommonly, a focal venous stenosis of the draining vein may be observed, typically at the point where the draining vein penetrates the dura to enter the dural sinus (Fig. 5). Normal venous drainage of the affected brain is not seen. Neither arteriovenous shunting nor mass effect is present. It

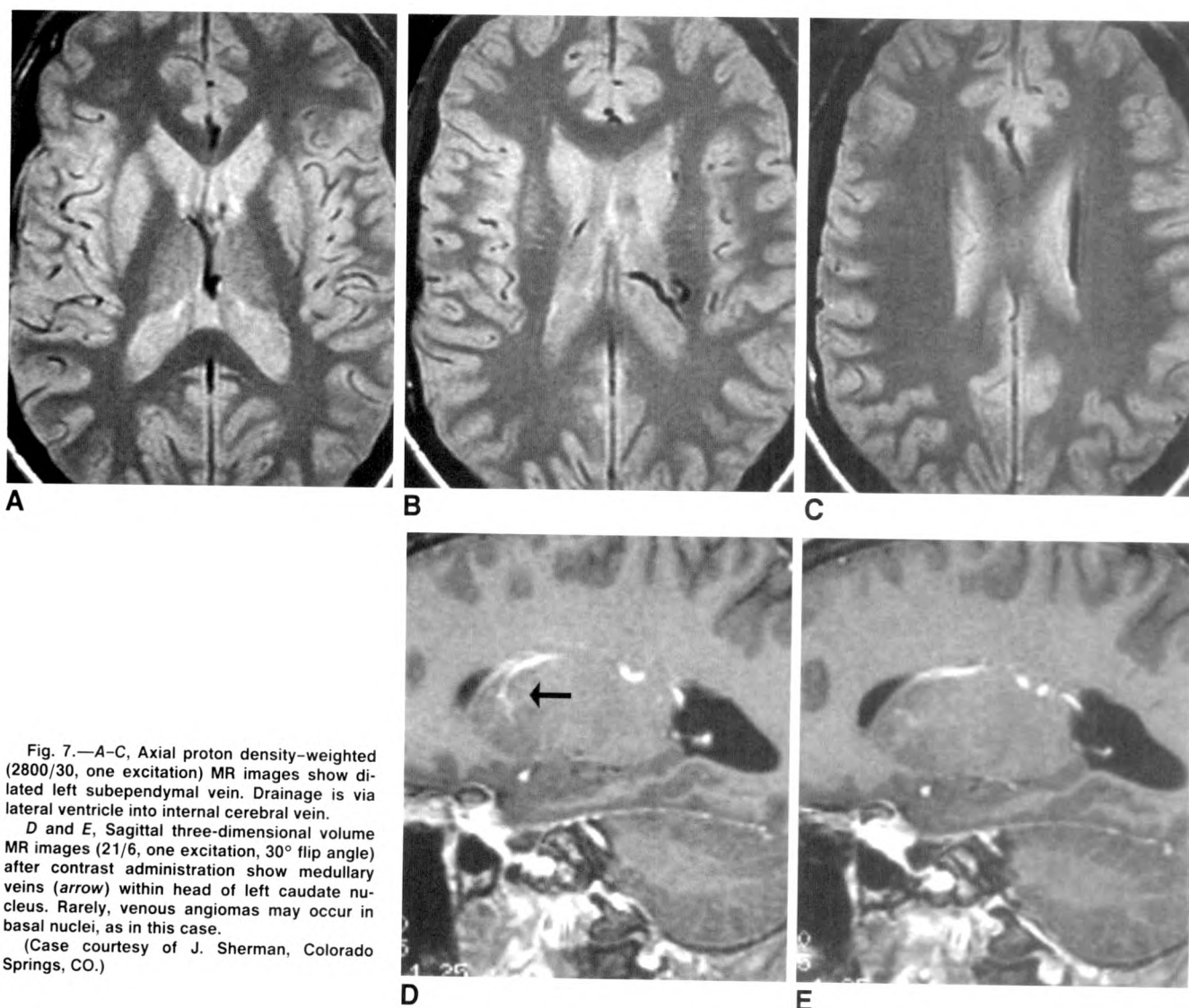


Fig. 7.—A–C, Axial proton density-weighted (2800/30, one excitation) MR images show dilated left subependymal vein. Drainage is via lateral ventricle into internal cerebral vein.

D and E, Sagittal three-dimensional volume MR images (21/6, one excitation, 30° flip angle) after contrast administration show medullary veins (arrow) within head of left caudate nucleus. Rarely, venous angiomas may occur in basal nuclei, as in this case.

(Case courtesy of J. Sherman, Colorado Springs, CO.)

is worth noting that today, patients with uncomplicated venous angioma no longer undergo angiography. Rather, only those patients with complications of venous angioma, such as hemorrhage or infarction, are studied. As such, venous angioma of the brain is not usually seen during the early venous phase, but rather during the late venous phase, because venous restrictive disease causes delayed filling and emptying of the angioma.

CT

As with other imaging techniques, such as MR imaging and angiography, with contrast-enhanced CT, the draining vein of a venous angioma is readily detected as a linear or curvilinear focus of enhancement, typically coursing from the deep white matter to a cortical vein or a deep vein or to a dural sinus. Commonly reported in the early CT descriptions is a round, 1- to 2-cm focus of enhancement within the deep white matter or rarely in the striatum.

MR Imaging

On MR images, venous angiomas characteristically have a transhemispheric flow void on both T1- and T2-weighted images. Frequently, spatial misregistration artifact is noted with proton density- and T2-weighting [35]. Most likely, this artifact accounts for the hyperintensity on T2-weighted images described in early reports. Spatial misregistration artifact will be absent, however, in cases in which the draining vein courses parallel or perpendicular to the phase-encoding direction (Figs. 1 and 4). In such cases, only a focal flow void within the brain parenchyma will be observed. After the administration of MR contrast material because of slow flow, significant enhancement of both the draining vein and often the caput medusae of medullary veins may be seen.

In complicated venous angioma, associated hemorrhage, cavernous angioma or, exceptionally, nonhemorrhagic venous infarction may be seen (Fig. 5). MR angiography also may be helpful in such patients. The primary reasons to perform MR angiography are to exclude an arterial (treatable)

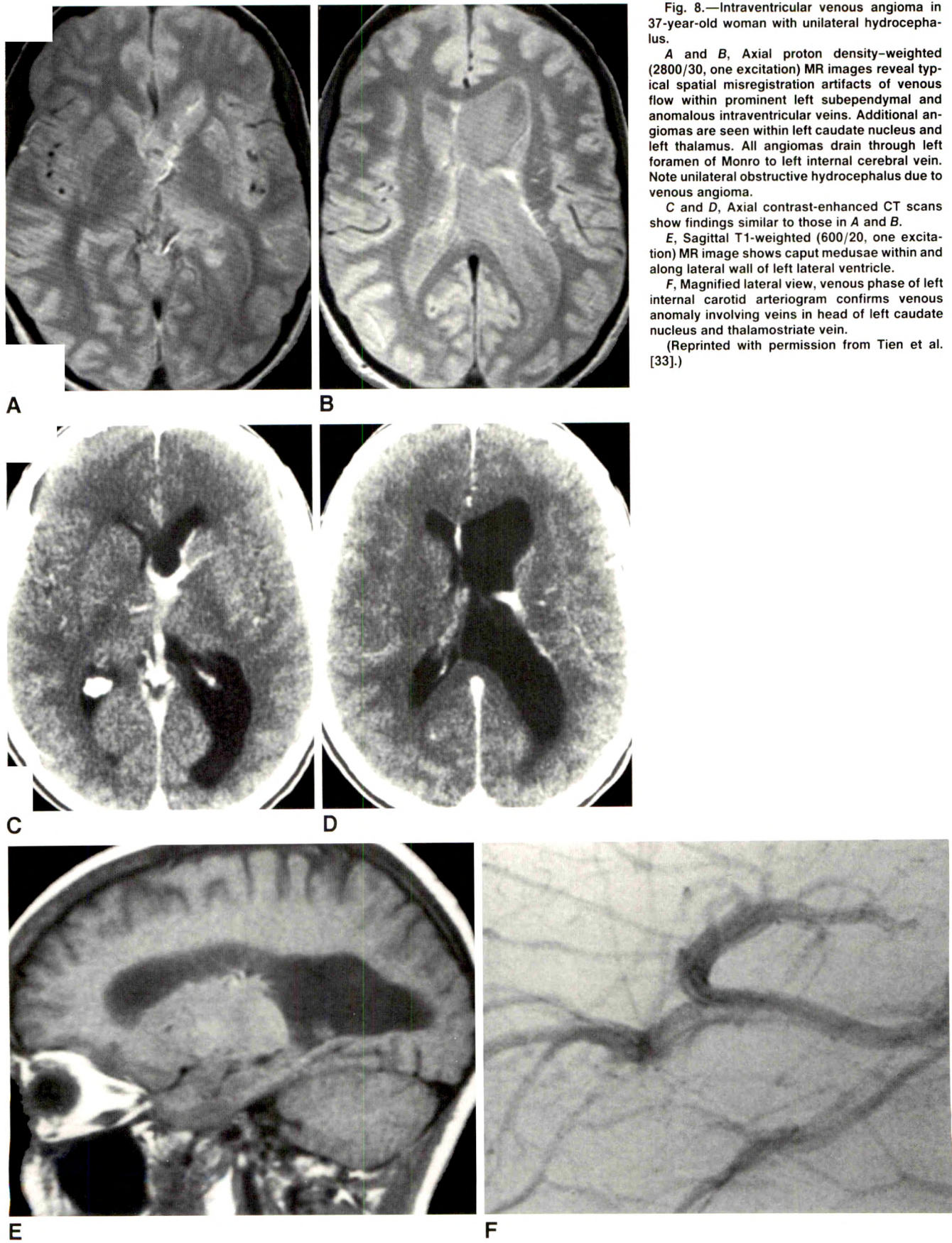


Fig. 8.—Intraventricular venous angioma in 37-year-old woman with unilateral hydrocephalus.

A and B, Axial proton density-weighted (2800/30, one excitation) MR images reveal typical spatial misregistration artifacts of venous flow within prominent left subependymal and anomalous intraventricular veins. Additional angiomas are seen within left caudate nucleus and left thalamus. All angiomas drain through left foramen of Monro to left internal cerebral vein. Note unilateral obstructive hydrocephalus due to venous angioma.

C and D, Axial contrast-enhanced CT scans show findings similar to those in A and B.

E, Sagittal T1-weighted (600/20, one excitation) MR image shows caput medusae within and along lateral wall of left lateral ventricle.

F, Magnified lateral view, venous phase of left internal carotid arteriogram confirms venous anomaly involving veins in head of left caudate nucleus and thalamostriate vein.

(Reprinted with permission from Tien et al. [33].)

component of the lesion and to exclude focal stenosis of the terminal draining vein where it enters the dural sinus. Arterial (three-dimensional time-of-flight or phase contrast) and venous (two-dimensional time-of-flight immediately after contrast administration or three-dimensional phase contrast with a velocity-encoding gradient of 5–10 cm/sec) MR angiograms should be obtained, preferably without presaturation bands.

One recently described feature on MR images may be a useful marker of which venous angiomas are more likely to hemorrhage. Occasionally, after the administration of MR contrast material, variable enhancement of the brain parenchyma may be seen (Fig. 4). As suggested by Dillon et al. [27] (ASNR meeting, June 1991), this enhancement may indicate venous restrictive disease in association with the draining vein. If this proves valid, venous angiomas with enhancing parenchyma may be more likely to hemorrhage.

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Pictorial Essay

Normal Anatomy of the Hippocampus and Adjacent Temporal Lobe: High-Resolution Fast Spin-Echo MR Images in Volunteers Correlated with Cadaveric Histologic Sections

Robert D. Tien,¹ Gary J. Felsberg,¹ and Barbara Crain²

This essay illustrates the appearances of sections of the normal hippocampus and adjacent temporal lobe on high-resolution heavily T2-weighted fast spin-echo MR images and correlates them with histologic sections. We found that this MR examination showed the detailed anatomy of the normal hippocampus in a much shorter time than is possible with conventional spin-echo techniques. The information provided in this essay can be used as a baseline for distinguishing between normal and abnormal hippocampi in a variety of disease states.

The hippocampus is an important structure in the brain that is involved in numerous diseases. Visualization of the hippocampus with MR imaging has therefore been extremely useful in detecting such pathologic entities as hippocampal sclerosis or atrophy in patients with temporal lobe epilepsy and Alzheimer's disease [1]. Although gross estimates of hippocampal size and signal abnormality have clinical value [2], we think that more precise imaging can help to further delineate the fine anatomic detail of the hippocampus and thus provide more sensitive detection and localization of lesions in this structure. Anatomic details of the hippocampus shown on T1-weighted images (5-mm-thick sections) correlate closely with anatomic findings in cadaveric sections [3]. However, imaging can be improved by using a recently described MR pulse sequence, fast spin echo, a method that allows acquisition of

heavily T2-weighted (long TR/long TE) images and large-matrix examinations in clinically acceptable time periods. With this technique, anatomic detail is improved because thin sections (2 mm), a high-resolution matrix (256 × 256), and four excitations can be used. In addition, it may be possible to detect signal abnormalities involving the hippocampus. We correlated the fast spin-echo images of the hippocampus and medial temporal lobe structures in eight healthy volunteers with histologic sections from a normal cadaveric brain.

Fast Spin-Echo MR Imaging in Healthy Volunteers

MR images of the brains of eight healthy young adult volunteers (mean age, 32 years) were obtained with a 1.5-T superconducting magnet (Signa, General Electric, Milwaukee, WI). A sagittal localizer sequence was used first. This generated parasagittal images through the long axis of the hippocampus, from which orthogonal coronal fast spin-echo images were prescribed to cover the entire length of the hippocampus (Fig. 1). Each person was then imaged by using a standard quadrature head coil and fast spin-echo techniques with the following image parameters: 2-mm-thick sections with interleave (the minimal slice thickness in our current fast spin-echo software), 256 × 256 matrix, 18-cm field of view, 4000/100/4 (TR/TE/excitations) sequences, echo train length of 16, and

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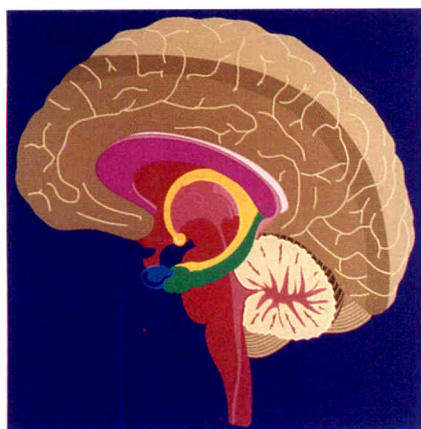
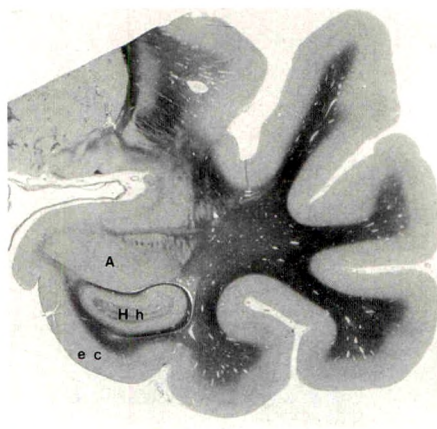


Fig. 1.—Drawing shows left lateral view of limbic system. Hippocampus (green) is located in medial temporal lobe and has an arclike configuration ending in region of splenium of corpus callosum. Fimbria of hippocampus (yellow), which is formed by alveus, in turn becomes fornix (yellow) at level of hippocampal tail. Amygdala (blue) is immediately rostral to hippocampal head.

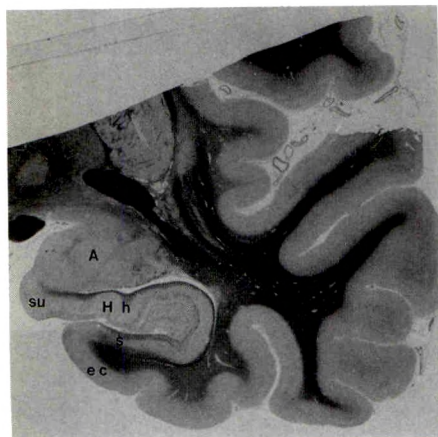


A



B

Fig. 2.—A and B, Histologic section (A) through anterior hippocampal head (Hh) and corresponding slightly anterior fast spin-echo coronal MR image (B). Gray matter of hippocampal head is inferior to temporal horn; gray matter of amygdala (A) is superior and anterior to hippocampal head. Lateral aspect of hippocampal head is limited by temporal horn; medially, entorhinal cortex (ec) can be identified within parahippocampal gyrus.



A



B

Fig. 3.—A and B, Histologic section (A) through hippocampal head (Hh) slightly posterior to Fig. 2A and corresponding fast spin-echo coronal MR image (B). Hippocampal head can be seen consistently on MR by identification of hippocampal digitations, which give a characteristic waviness to hippocampus at this level. Hippocampal head is separated from gray matter of amygdala (A) (mid to posterior portions) by temporal horn. Note subiculum (s), which is lateral continuation of entorhinal cortex (ec). Subiculum in gyrus uncinatus (su) joins hippocampal head to amygdala.

16-kHz bandwidth. With this method, 30 sections can be obtained in 12 min 50 sec. The rationale for choosing an echo train length of 16 instead of eight was as follows: Although an echo train length of eight may offer a better signal-to-noise ratio with lower resolution matrices (256×128), with a higher resolution matrix size such as 256×256 , the gain in the signal-to-noise ratio when an echo train length of eight is used rather than one of 16 is minimal and results in a doubling of image time. Although not shown in this essay, proton density-weighted fast spin-echo images can also be obtained that in our experience are comparable to conventional spin-echo images. However, there is an additional time penalty if proton-density images are to be obtained.

The fast spin-echo technique is a hybrid based on a rapid-acquisition relaxation-enhanced method initially described by Hennig et al. [4]. This fast spin-echo sequence consists of a 16-echo Carr-Purcell-Meiboom-Gill train with an echo spacing

between 15 and 18 msec. In this technique, a single RF pulse is followed by an echo train in which each echo is individually phase encoded and then read in the presence of a frequency-encoding gradient. T2-weighted images are acquired in substantially less time than when conventional spin-echo techniques are used (in our case, 12 min 50 sec for fast spin echo compared with 137 min 4 sec for conventional spin-echo technique with similar parameters).

Histologic Sections from a Cadaver

A brain from a person with no history of neurologic disease and no neuropathologic findings at autopsy was selected for examination. After 2 weeks' fixation in 20% formalin, the temporal lobe was removed and cut perpendicular to its long axis in order to mimic the angle used for MR imaging. Blocks 3–4 mm thick were obtained throughout the entire length of

the temporal lobe. These were embedded in paraffin and sectioned at 8 μ m. Sections from each block were stained with either cresyl violet or hematoxylin and eosin with a Luxol fast blue counterstain for myelin. The stained sections were matched to the MR images, and individual temporal lobe structures were then determined both on MR images and cadaveric histologic sections according to anatomic references [5].

MR-Histologic Correlation

Fast spin-echo MR images of the brain showed excellent anatomic detail, with no significant variance in the shape of

the hippocampus among the eight persons examined. Figures 2–7 are a representative anterior to posterior series of images, matched as closely as possible with the corresponding histologic sections.

Anatomy of the Hippocampus and Adjacent Temporal Lobe Structures

The hippocampus consists of two major parts, the cornu Ammonis (hippocampus proper) and the dentate gyrus, which are separated by the hippocampal sulcus (Fig. 5C). Below the hippocampal sulcus or fissure is the subiculum, which occupies the medial/superior curvature of the parahippocampal

Fig. 4.—A and B, Histologic section (A) through junction of hippocampal head (H) and body slightly posterior to Fig. 3A and corresponding fast spin-echo coronal MR image (B). At this level, hippocampus gradually loses characteristic waviness of hippocampal digitations that mark hippocampal head. Posterior portion of amygdala (A) is separated from hippocampus by temporal horn. Subiculum (s) between entorhinal cortex and first field of hippocampus (cornu Ammonis 1) can be easily identified, as can subiculum in gyrus uncinatus (su) between hippocampal head and amygdala.

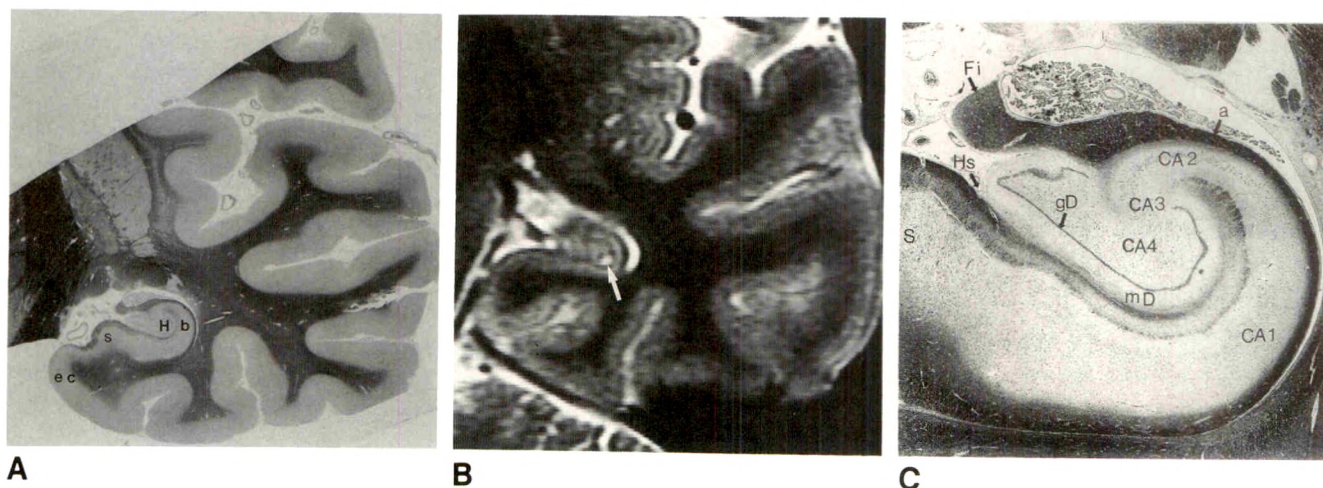
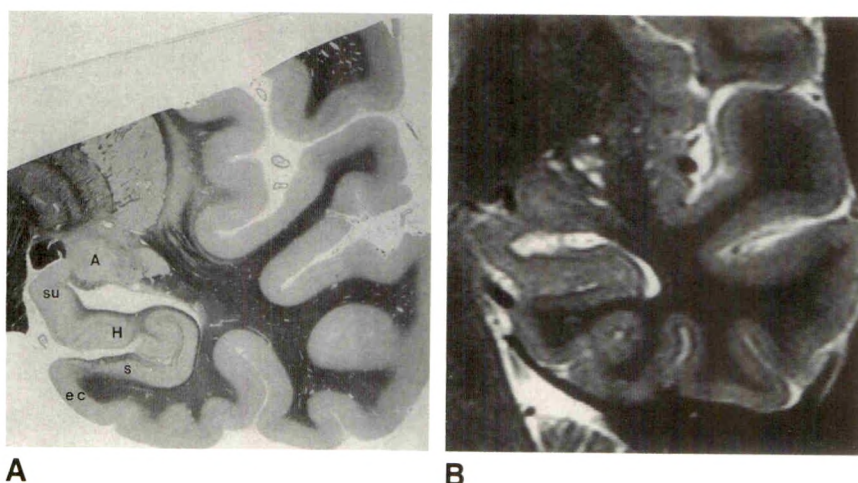


Fig. 5.—A and B, Histologic section (A) through hippocampal body (Hb) and corresponding fast spin-echo coronal MR image (B). At level of hippocampal body, waviness characteristic of hippocampal head is completely absent. Temporal horn can be identified defining lateral aspect of hippocampal body, whereas choroidal fissure defines cranial aspect of hippocampal body. Also note absence of gray matter of amygdala at level of hippocampal body. MR image shows some persistence of hippocampal sulcus at lateral/inferior aspect of body (arrow); this normal structure is commonly identified and should not be mistaken for pathologic change. S = subiculum, ec = entorhinal cortex.

C, Higher magnification of area of hippocampal body in A. The four regions of the cornu Ammonis (CA1, CA2, CA3, CA4), comprising pyramidal neurons, are well seen. CA1 field is the largest cellular field and represents lateral continuation of subiculum (S). CA2 field appears at cranial aspect of cornu Ammonis before curving into region of dentate gyrus. CA3 field is transitional portion of cornu Ammonis, with CA4 field surrounded by dentate gyrus. Alveus (a) is a compact white matter tract of efferent axons separating hippocampus from temporal horn. Fimbria (Fi) represents free edge of this white matter tract and appears at cranial limit of hippocampus; fimbria ultimately forms fornix in region of hippocampal tail. Dentate gyrus has two layers: the densely packed granular layer (gD) above the adjacent, loosely packed neuropil of the molecular layer (mD). Hippocampal sulcus (Hs) represents embryonic fissure between dentate gyrus and cornu Ammonis; it is usually obliterated during development, although commonly traces may remain (see B).

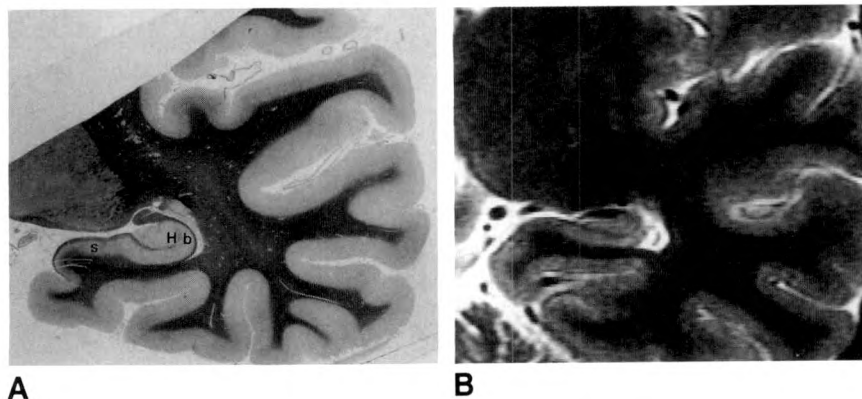


Fig. 6.—A and B, Histologic section (A) through hippocampal body (Hb) slightly posterior to Fig. 5A and corresponding fast spin-echo coronal MR image (B). Although temporal horn in region of hippocampal head lacks choroid plexus, choroid plexus is commonly identified in temporal horn at level of hippocampal body. Fimbria attains its greatest size at this level before forming fornix at tail of hippocampus. s = subiculum.

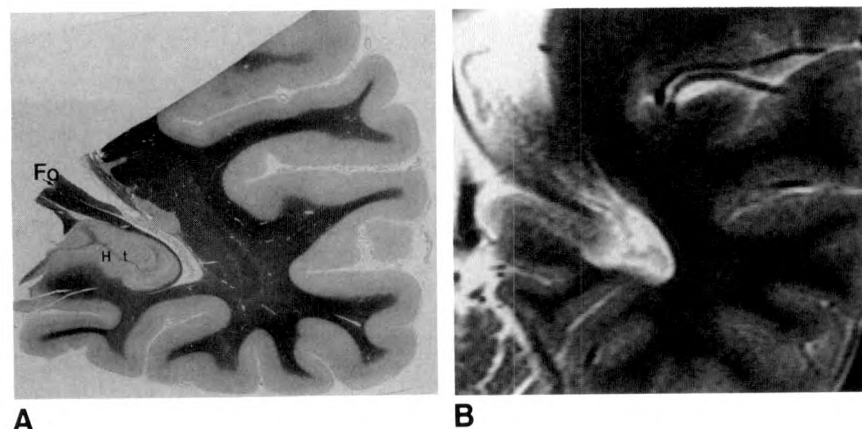


Fig. 7.—A and B, Histologic section (A) through hippocampal tail (Ht) and corresponding fast spin-echo coronal MR image (B). Tail is characterized by alveus/fimbria forming fornix (Fo) covering its cranial aspect. Hippocampal tail bulges into choroid plexus containing atrium of lateral ventricle.

gyrus and runs superolaterally to its border with the hippocampus. The hippocampus, which represents primitive or allocortex, is therefore separated from the temporal neocortex (specifically, the entorhinal cortex and the rest of the parahippocampal gyrus) by the transitional zone (periallocortex) of the subiculum.

The hippocampus proper consists of six layers: the alveus, stratum oriens, stratum pyramidale, stratum radiatum, stratum lacunosum, and stratum moleculare. The alveus (Fig. 5C) covers the portion of the hippocampus that protrudes into the temporal horn of the lateral ventricle and is the main efferent path followed by hippocampal and subicular axons. The alveus continues medially to form the fimbria of the hippocampus, which in turn joins the fornix. Stratum lacunosum contains some of the efferent fibers to the hippocampus. The remaining four layers of the hippocampus are gray matter consisting primarily of pyramidal neurons, dendrites, and collateral axons. Because of the different appearances and different connections of the pyramidal neurons, the cornu Ammonis is usually divided into four fields, CA1, CA2, CA3, and CA4, which are labeled in Figure 5C. CA1 is adjacent to the subiculum and is by far the largest of these areas. It contains small, scattered neurons, which are roughly divided into two sublayers. CA2 contains pyramidal cells packed into a single dense layer; it generally appears at or near the superior aspect of the cornu Ammonis. CA3 is located at or near the curve of the cornu Ammonis as it enters the hilum

of the dentate gyrus. CA4 consists of a dispersed population of pyramidal cells scattered within this hilum.

The dentate gyrus envelops field CA4 of the cornu Ammonis and is separated from CA1–CA3 and the subiculum by the hippocampal fissure (Fig. 5C). The hippocampal fissure is usually obliterated during development, although a persistent cavity often remains (Fig. 5B). The two most prominent layers within the dentate gyrus are the densely packed layer of cell bodies called the granular layer and the adjacent neuropil called the molecular layer (Fig. 5C).

Specific Anatomic Features of the Hippocampus and Adjacent Temporal Lobe Structures Important for Interpretation of MR Images

With continuing refinements in MR technology, finer anatomic details of the hippocampus can be identified. While the cellular structures of the hippocampus proper are currently beyond the resolution of current techniques, some anatomic structures can be identified consistently. The hippocampus, like the caudate nucleus, forms an arc running roughly rostral to caudal in the medial temporal lobe with a head (also known as the pes hippocampi), body, and tail that are approximately 4 cm long [5] (Fig. 1). The hippocampal head (pes hippocampi) (Figs. 2 and 3) is marked by the hippocampal digitations, which are sagittally oriented enfoldings of the various layers

of the hippocampus proper, each surrounding a digital extension of the dentate gyrus. The amygdala is directly anterior/superior to the hippocampal head and the uncus recess is directly anterior to the hippocampal head. Laterally, the head bulges into the temporal horn; this region of the ventricle is free of choroid plexus. Medially, the pes hippocampi continues into the posterior portion of the uncus. (The uncus is the anterior segment of the parahippocampal gyrus. It includes the entorhinal cortex, Brodmann's area 28.)

The hippocampal body lacks the digitations of the hippocampal head (Figs. 5 and 6). The deep aspect of the hippocampal body forms a portion of the floor of the temporal horn; it protrudes into the ventricle and is covered by the alveus and the ependyma. Choroid plexus in the temporal horn covers this surface, which is composed primarily of fields CA1-CA3. The superficial aspect of the body is adjacent to the fimbria, which extends superiorly and medially over the dentate gyrus.

The hippocampal tail (Fig. 7) forms an arc posteriorly and occupies a portion of the floor of the atrium and curves along the inferior surface of the splenium. It is covered by the white matter of the alveus and by ependyma superolaterally. The alveus is continuous with the fimbria, which in turn forms the thin crura of the fornices.

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- Papers must be submitted on the clinical application of the discipline of radiology and radiological science.
- The event is open to residents in radiology and radiological sciences. If not the sole author, it is expected that the resident will have performed the majority of the work and be the senior author.
- Manuscripts should not exceed 5,000 words and 10 illustrations.
- Winners will be announced by March 16, 1993.
- Papers will be presented at the American Roentgen Ray Society 93rd Annual Scientific Meeting at the San Francisco Marriott, San Francisco, CA, April 25-30, 1993, and be submitted for publication to the *American Journal of Roentgenology*.
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Book Review

MRI Physics for Radiologists. A Visual Approach, 2nd ed. By Alfred L. Horowitz. New York: Springer-Verlag, 187 pp., 1992. \$25

This book is meant to provide basic, nonmathematical explanations of the fundamental principles of MR imaging. Overall, the text succeeds in introducing complex concepts to readers new to the field and can be recommended for that purpose. Attention is called to the subtitle, "A Visual Approach," which refers to graphic presentations *not* MR images. Readers not familiar with MR imaging should also be cautioned that some explanations are somewhat nonstandard (e.g., definitions of pulse sequences, macroscopic magnetic moment) and demand further study to avoid misconceptions.

The book has 19 chapters divided into three thematic sections. Section 1, "Image Contrast," deals with magnetic fields, RF pulses, relaxation, pulse sequences, and signal phase. Particularly good discussions are presented for the concept of vectors, instrument conventions, RF, T1 and T2 weighting, and signal phase. Section 2, "The Image in Space," includes information on gradients, Fourier

transformation, phase encoding, and signal processing. The discussions on phase encoding and signal processing are notable. Section 3, "Miscellaneous Topics," includes fast scanning, three-dimensional and half-Fourier imaging, flow and motion phenomena, chemical shift, and MR artifacts.

Although quite readable, the type and layout may not be suited to all. The graphics and highlights at times reflect desktop construction, but overall they not only are useful but also provide significant insight into complex theoretical constructs. Although the book has only 15 general references, most are useful and pertinent (reference 2 is incorrectly specified). Overall this text is affordable and useful for the intended audience.

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Pictorial Essay

MR Myelography Using Heavily T2-Weighted Fast Spin-Echo Pulse Sequences with Fat Presaturation

Adrian G. Krudy¹

A new method for generating myelogramlike images of the thecal sac by MR imaging is presented. The method is based on suppressing background signal by using heavily T2-weighted fast spin-echo pulse sequences and obliterating fat signal by presaturation. The resulting slices are then projected into a composite image using a standard maximum intensity projection (MIP) algorithm. The technique is implemented with commercially available hardware and software and yields reproducible high-quality images of the lumbar thecal sac, which show excellent definition of the thecal margins, nerve roots, and nerve root sheaths. This method could replace conventional lumbar myelography and postmyelographic CT studies.

MR imaging has, to a large degree, replaced myelography and CT as the primary diagnostic technique in the imaging of spinal disease. Nevertheless, conventional myelography, often in conjunction with CT, is still widely used. Prior MR myelographic techniques have included a nontomographic projection approach using the RARE (rapid acquisition with relaxation enhancement) pulse sequence, proposed by Hennig et al. [1] in 1986, and a three-dimensional volume technique with maximum intensity projection (MIP) using a fast imaging with steady-state precession (FISP) gradient sequence, proposed by Ross et al. [2] in 1991. The purpose of this essay is to illustrate a new MR method for generating myelogramlike images of the thecal sac.

Technique

A 1.5-T Signa MR system (General Electric Medical Systems, Milwaukee, WI), 4.7.9 Advantage software, and the Get Fast rapid spin-echo software package are used for image acquisition. The General Electric independent console workstation, 3.01 version software, and the interactive vascular imaging advanced software package are used for subsequent manipulation. All pulse sequences are standard on the unit and are approved by the Food and Drug Administration.

Preliminary T1-weighted images are obtained in the sagittal and transverse planes for localization. A two-dimensional Fourier transform book of images of the lumbar region is obtained in either the coronal or the angled coronal plane. Additional left and right shallow oblique (30–35°) coronal images are planned on the basis of the transverse preliminary images, centering on the L4–L5 disk space. Sagittal and transverse views are obtained in routine fashion using identical imaging parameters. For evaluation of the conus medullaris, a coronal image is obtained by centering on the L2 level and angling the images parallel to the long axis of the thecal sac. A fast spin-echo sequence with a 16-echo train is used with 6000/200 (TR/TE), 5-mm slice thickness, 1-mm interslice gap, 256 × 256 matrix, four excitations, and a 16-cm field of view. Fat signal is eliminated by using a standard fat presaturation pulse and centering the receiver frequency on water. A no-phase-wrap option is used to minimize aliasing artifact.

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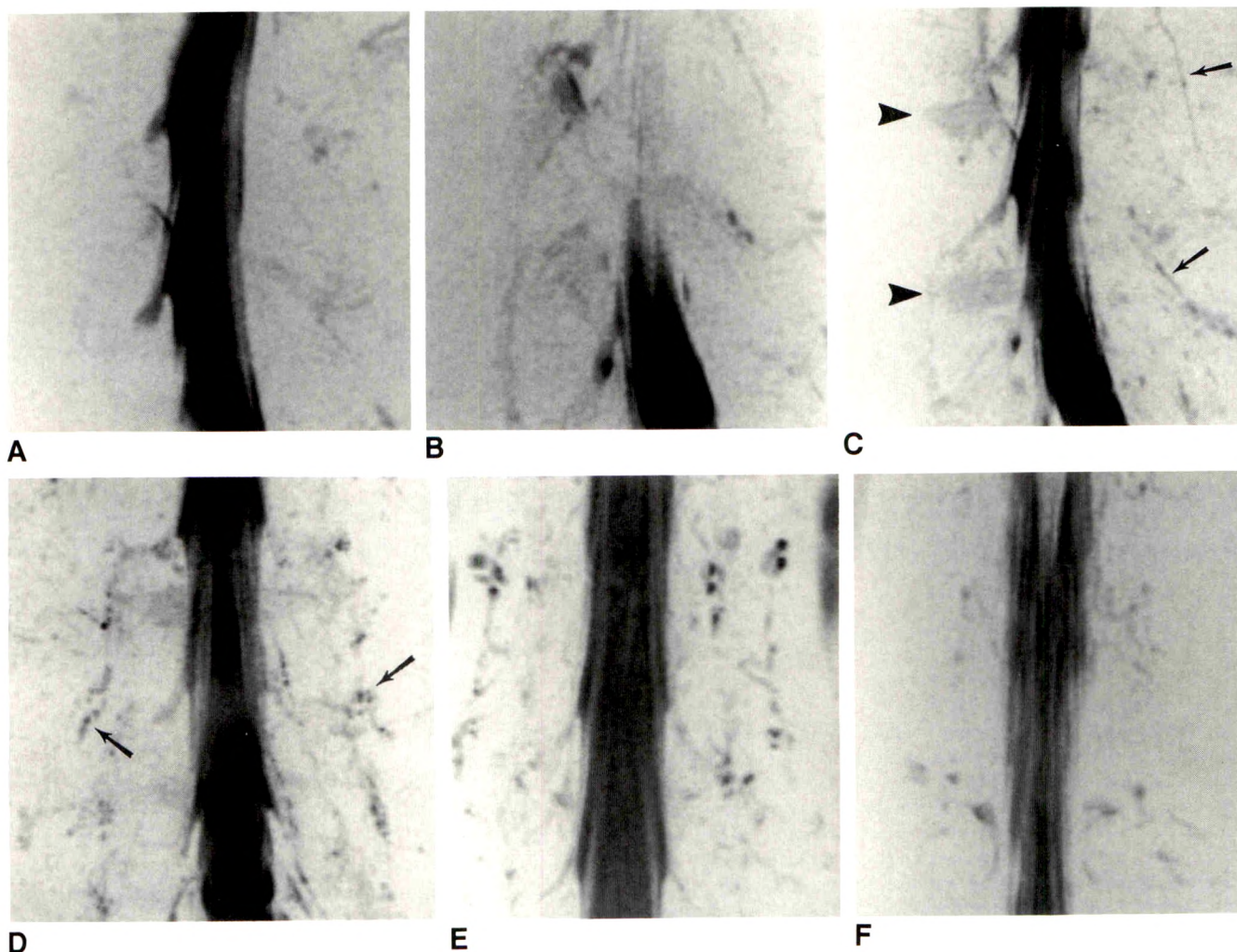


Fig. 1.—22-year-old healthy volunteer.

A and B, Two selected individual oblique MR images (5 mm thick, 1-mm gap) from a book of 14 images.

C, Maximum intensity projection (MIP) image produces MR myelogram. Note good definition of thecal sac, nerve roots, and nerve root sheaths, with excellent background suppression. Note small vessels (arrows) in paravertebral musculature and faintly seen disks (arrowheads).

D, Coronal MR myelogram shows excellent background suppression. Note multiple small vessels (arrows) in paravertebral region and in paraspinous soft tissue.

E, Coronal MIP myelogram of upper lumbar region.

F, Single coronal MR image of 5-mm section from same study as E shows improved definition of conus and cauda equina compared with E. (Fig. 1 is continued on the opposite page.)

Typically, 14–17 images (Figs. 1A and 1B) can be obtained in 6 min 24 sec (256 × 256 matrix). The resultant individual images are examined. Those images that contain visible portions of the thecal sac are then selected and subjected to a standard MIP algorithm on the workstation. The resultant composite projection image is a myelogramlike image in one plane. The sequence is repeated for each desired projection (Figs. 1C–1G). No MIP image is generated from the axial images (Fig. 1H). Reverse video (black on white background) display and filming is used to enhance perception of the thecal sac and nerve roots. Because the bone landmarks are lost, the level of the myelogram must be electronically ascertained by placing a cursor at a neural foramen on the preliminary T1-weighted sagittal image and marking the same level with a cursor on the MIP image.

The level of the transverse images is determined by a reference sagittal image on which the axial image levels are automatically labeled. Faster images, with slight degradation in image quality, can be obtained with 5500/250, 192 × 256 matrix, and two excitations, resulting in a scanning time of 2 min 12 sec.

Lumbar Spine

Images of the lumbar area obtained with this technique are of excellent quality. The combination of fat saturation and a long TR of 6000 msec results in excellent suppression of all background signal except that from fluid-containing structures. Small paravertebral vessels are visible but do not obscure the thecal sac. Occasionally, these small vessels

Fig. 1.—(Continued).

G, Lateral MR myelogram of lumbar region.

H, Transverse T2-weighted MR myelogram shows extremely high contrast of thecal sac compared with surrounding bone and soft tissue. Note excellent definition of nerve roots.

I, Effect of varying TE from 161 msec to 299 msec with a constant TR of 6000 msec. Progressive suppression of background vessels occurs with longer TE of 299 msec (*lower right*). CSF appears to be slightly darker on image with shorter echo time (TE = 161 msec) image (*upper left*) and obscures part of centrally coursing nerve roots. Nerve root sheaths are equally well seen on image with longer TE.

G

H

6000/161

6000/207

6000/253

6000/299

I

Fig. 2.—Healthy volunteer.

A, Coronal MR myelogram shows left L5 nerve root partially obscured and overlapped by a small vessel (*arrow*).

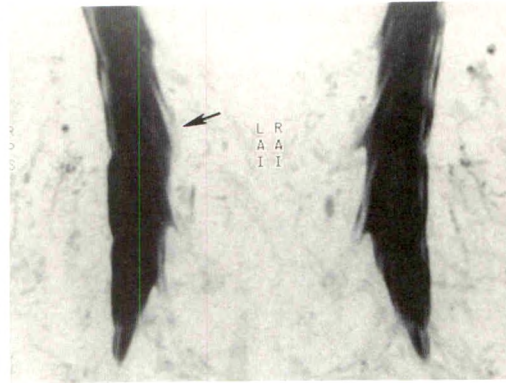
B, MIP MR myelogram electronically rotated a few degrees clearly shows nerve root (*arrow*) separate from vessel. Slight blurring occurs when image is rotated off axis.

A

B

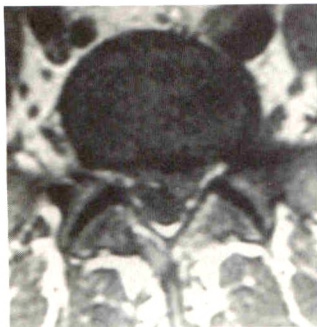


A



B

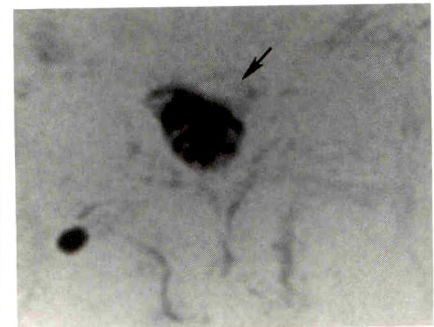
Fig. 3.—35-year-old man with pain in left leg.
A, Transverse MR image shows lateral disk (arrowhead) at L5-S1 neural foramen.
B, Oblique MR myelograms show amputation of left L5 nerve root sheath (arrow).



A

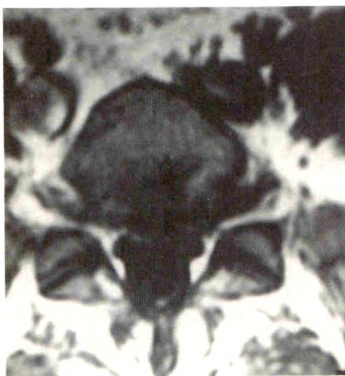


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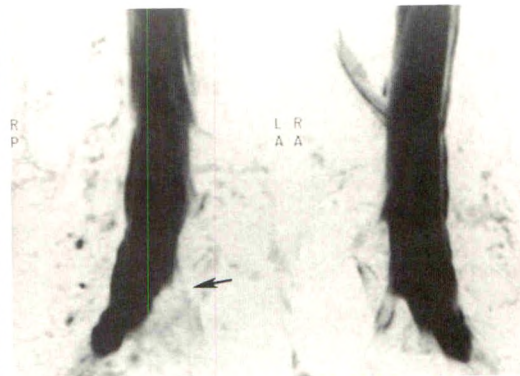


C

Fig. 4.—34-year-old man with pain in lower back and left leg.
A, MR image shows large left-sided herniation of L5 disk.
B, Oblique MR myelograms show large left-sided indentation (arrow) on thecal sac and amputation of left S1 nerve root sheath.
C, Transverse MR myelogram at L5 disk level shows compression of left anterior aspect of thecal sac (arrow) by herniated disk.

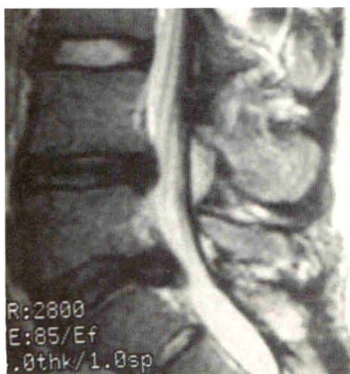


A

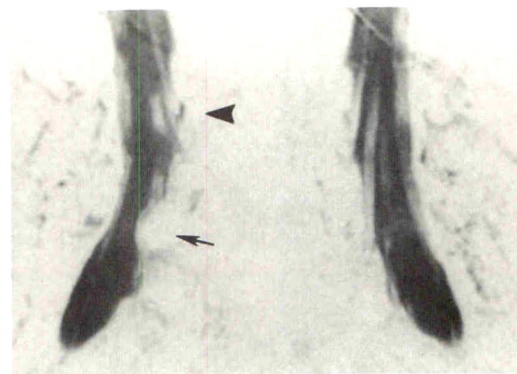


B

Fig. 5.—36-year-old woman with pain in left leg.
A, MR image shows a left-sided disk herniation at L5.
B, Oblique MR myelograms show amputation of left S1 nerve root sheath (arrow).



A



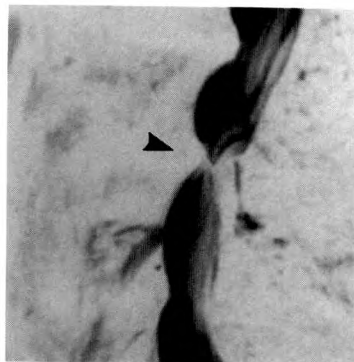
B

Fig. 6.—24-year-old man with pain in lower back and left leg.
A, Sagittal T2-weighted fast spin-echo MR image shows a moderate to large L5 disk herniation and moderate central L4 disk herniation. On transverse views (not shown), L4 disk was central and L5 disk was in left paramedian position.
B, Oblique MR myelograms show a large indentation on left thecal sac at L5 with amputation of left L5 nerve root sheath (arrow). A central defect (arrowhead) is visible at L4, corresponding to L4 disk herniation.

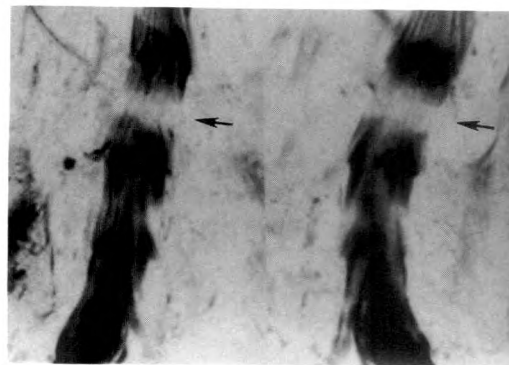
Fig. 7.—81-year-old woman with pain in back and right leg.

A, Lateral MR myelogram elegantly shows spinal stenosis at L3 (arrowhead) with associated disk bulging. Bulging disks are also seen at L2 and L4 levels.

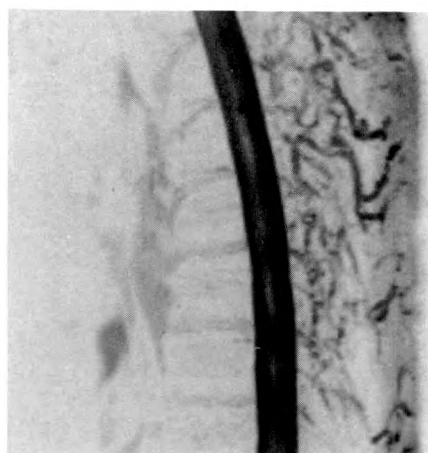
B, Oblique MR myelograms show typical appearance of spinal stenosis (arrows).



A



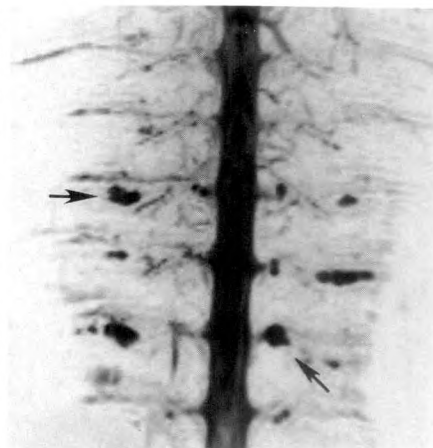
B



A



B



C

Fig. 8.—46-year-old healthy volunteer.

A, Lateral MR myelogram of thoracic spine shows well-defined margins of thecal sac, but cord is poorly shown.

B, Single 5-mm image from same series as A shows cord more clearly.

C, Coronal MR myelogram shows well-delineated margins of thecal sac, but spinal cord is poorly defined. Note flow artifact in upper thecal sac. Extensive small vessels are seen in chest wall and paravertebral region. Small dark areas (arrows) probably represent lymph nodes.

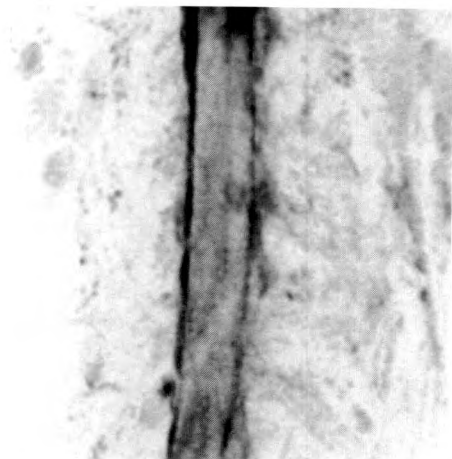


Fig. 9.—Oblique MR myelogram of cervical spine in 22-year-old healthy volunteer shows poor definition of lateral recesses and margins of thecal sac. Signal loss in CSF is thought to be due to flow of CSF.

overlap the nerve root sheaths. The signal from these vessels cannot be eliminated by using anterior and posterior presaturation pulses or contrast material. The prominence of these vessels, however, diminishes when echo time is lengthened (Fig. 1I). The MIP image can be rotated a few degrees, which often makes it possible to distinguish the nerve root sheath from vessels that had been superimposed (Fig. 2). Little change in the image of the thecal sac is noted as TR is varied from 4000 msec to 8000 msec. The MR myelograms show excellent contrast and resolution. The individual nerve roots can be seen coursing through the CSF and the definition of the CSF that extends into the nerve root sheaths is good. Individual images or partitions can sometimes show individual nerves better than the MIP image can. In the upper lumbar region, the conus medullaris and the cauda equina have good definition on the MIP image, although both these structures are better seen on the individual partitions (Figs. 1E and 1F). Transverse images of the thecal sac show extremely high

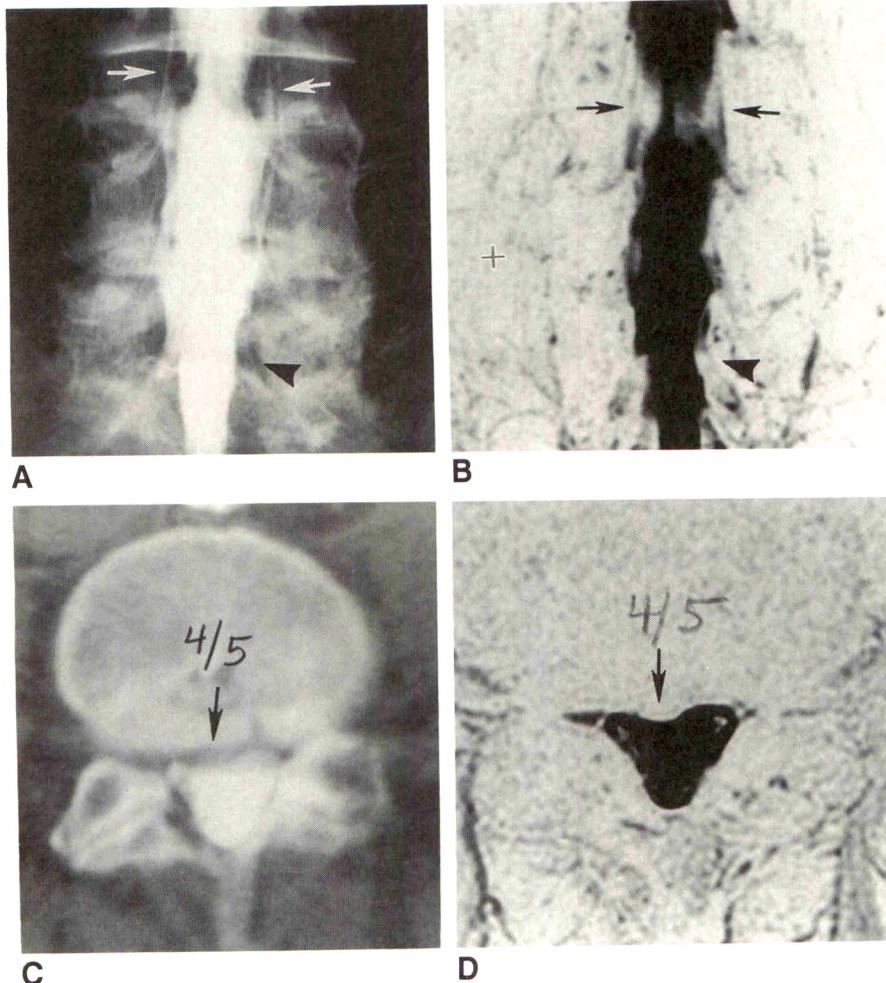


Fig. 10.—68-year-old man with numbness in right foot after two laminectomies.

A, Conventional contrast coronal myelogram shows arachnoiditis (arrows) at L2 level and amputation of left L5 nerve root sheath (arrowhead).

B, Corresponding MR myelogram shows similar appearance, with areas of arachnoiditis (arrows) and amputated L5 nerve root sheath (arrowhead).

C, CT scan obtained after myelography shows a mild right paramedian disk protrusion (arrow) at L4–L5 disk level.

D, Transverse MR myelogram at same level as C shows margins of thecal sac with higher contrast and shows disk protrusion (arrow) with greater clarity.

contrast with surrounding structures and excellent definition of the nerve roots (Fig. 1H). MR myelograms can show amputations of the nerve root sheaths (Figs. 3–6), indentations on the thecal sac from herniated disks (Figs. 4 and 6), and spinal stenosis (Fig. 7).

Thoracic Spine

Myelographic images of the thoracic spine obtained by using this technique are less useful. Although the margins of the thecal sac are well shown, definition of the cord is poor (Fig. 8). In addition, sagittal, coronal, and transverse images show an artifact in the CSF that is most likely a flow artifact. This technique, however, may be useful when a spinal block is encountered and reduced CSF flow is present.

Cervical Spine

Images obtained with this technique in the cervical region generally have poor quality because the increased CSF flow in this area results in signal loss (Fig. 9).

In summary, MR myelograms need to be compared with conventional myelograms and CT scans obtained after myelography in a large series, but in at least one case (Fig. 10), findings with these different imaging techniques have been similar.

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Computers in Radiology

Assessment of a Neuroradiology Picture Archiving and Communication System in Clinical Practice

S. L. Lou¹ and H. K. Huang

The goal of this study was to determine if our neuroradiology picture archiving and communication system (PACS) is capable of improving the efficiency and function of the management and review of neuroradiologic images. A neuroradiology PACS module developed in our department was evaluated in the clinical environment from February 1990 through July 1991. The overall evaluation focused on three aspects: (1) image delivery performance, (2) system availability, and (3) user acceptance. Image delivery performance was evaluated by analyzing the time spent on each modularized task with both the film-based system and the PACS system. The system availability was examined by observing the downtime occurrence and uptime probability of individual hardware components in the PACS module. User acceptance was evaluated through a survey done with the display workstation. Under regular operating conditions, the PACS outperforms the current film-based operation. The overall PACS module availability is more than 92%, with the display workstation available more than 99% of the time. The overall user acceptance of the system is 3.4 on a four-point ranking scale.

This study has demonstrated the full functionality and clinical usefulness of our neuroradiology PACS. On the basis of the results of this study, a large-scale PACS has been designed and implemented in our department.

Delays in film retrieval and missing films are two common major problems in most radiology departments. Although a departmental film library is responsible for the management of patients' films, these films may still be difficult to access.

One rational explanation for the unavailability of films is that there is competition for a patient's films among the several clinicians who are involved in a patient's case. This is especially true in the most critical cases, where several doctors need to review a patient's images. The films for these patients often will travel among physicians' offices, operating rooms, reading rooms, conference rooms, etc. The risk of losing films increases the more they are transferred between different locations. The unavailability of films is usually translated as inefficiency in a radiology department and can potentially reduce the quality of patient care provided.

We developed a picture archiving and communication system (PACS) module with an emphasis on neuroradiologic applications as a proposed solution to the above problems. With the concepts and techniques developed from this study, a fully operational PACS can be expanded to most sections in our department.

To evaluate its effectiveness, we embedded the PACS module in the real clinical environment for evaluation for 1½ years. The display workstation was installed in one of the reading rooms of the neuroradiology division. The film alternators were not eliminated in the reading room. The radiologists freely chose either the film-alternator system or the display workstation for their viewing practice. The workstation was used occasionally for morning and afternoon radiology rounds, as well as frequently for consultations with clinicians

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and visiting scholars and residents rotating through the neuroradiology division.

In this article, we first give an overview of the PACS configuration and major hardware. The data-base features, which include data concerning the patients and imaging data accumulated during the evaluation period, are then described. In the next section, we present the clinical evaluation of this PACS module. Finally, we assess the clinical value of the PACS and discuss potential improvements to the system.

System Hardware Architecture and Data Base

Figure 1 shows the hardware architecture of the neuroradiology PACS. It is composed of three subsystems: acquisition, data management, and display. All computer systems in the PACS are linked by an Ethernet communication network.

Image Acquisition Subsystem

The acquisition subsystem consists of three parts: (1) CT and MR stand-alone imaging systems, (2) computers that

capture images from the scanners (named capture computers), and (3) interface units between the scanners and the capture computers. During this evaluation period, our department operated three GE CT and three GE MR scanners (General Electric, Milwaukee, WI) at three different sites. One of the CT scanners is in the inpatient building and one of the MR scanners is in a research building, approximately 1.5 km away. The remaining two CT and two MR scanners are in the outpatient building across the street from the inpatient building (approximately 0.5 km away).

The method used to interface between the scanner and the acquisition (or capture) computer depends on the host computer in the scanner itself. An older scanner (for example, a GE 9800 CT scanner), which uses a single-task operating system, requires a special device (an American College of Radiology/National Electrical Manufacturers Association [ACR/NEMA] board) to interface with it in order to transfer imaging data to the capture computers. Newer scanners like the GE Signa MR scanner and the GE Highlight Advantage CT scanner have host computers that can operate in multitask mode; thus, the scanner can be connected to the capture

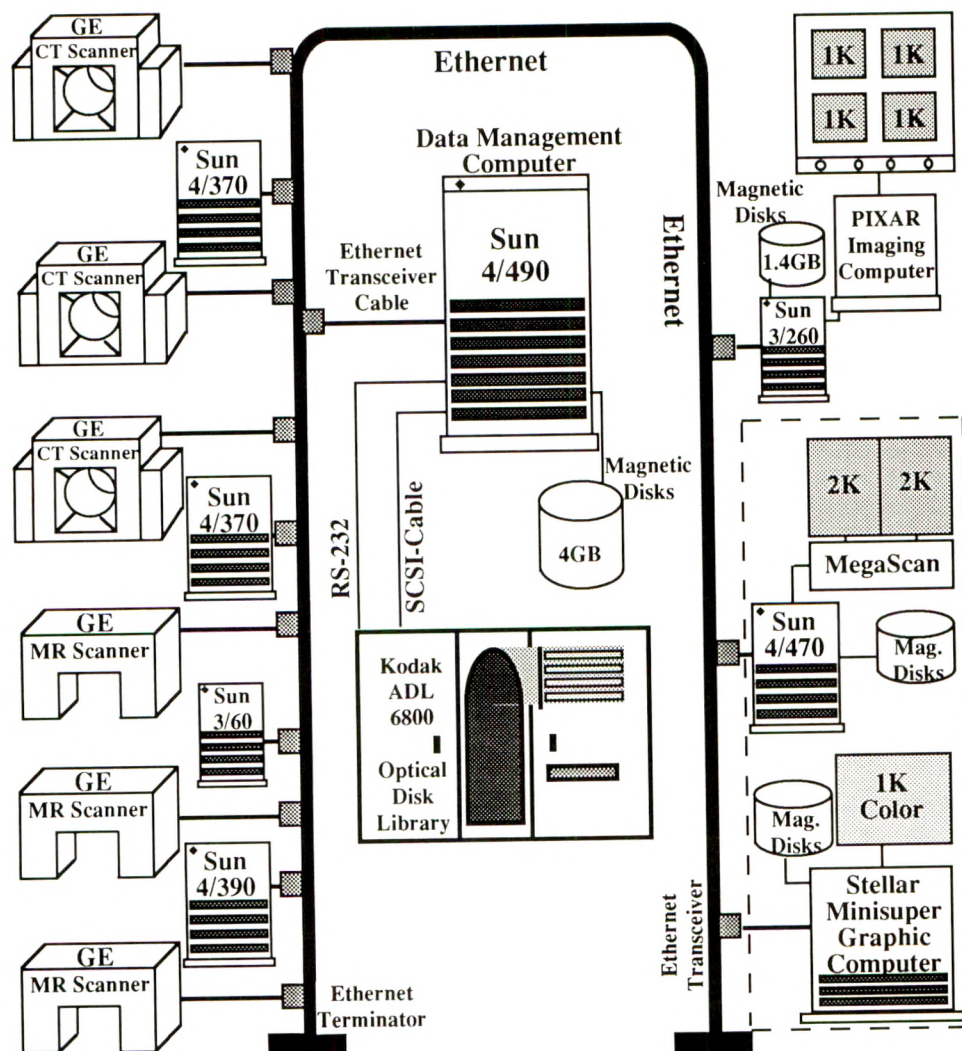


Fig. 1.—Hardware architecture of the neuroradiology CT/MR picture archiving and communication system. MegaScan and Stellar-based systems inside box outlined by broken line are not included in this study.

computer through the Ethernet communication protocol directly. The interface methods for each of these types of scanners were described by Weinberg et al. [1].

A capture computer is used to connect an individual CT or MR scanner to the data management subsystem; it is responsible for three tasks: decoding the received image description and data, reformatting images to a standard format, and transferring images to the data management host computer.

Data Management Subsystem

The data management subsystem is the core of this PACS module (center, Fig. 1) and is functionally equivalent to the neuroradiology administration office in the film-based management system. In general, this subsystem has four major functions: acquiring images from the capture computer, archiving images, distributing images to the display workstation, and serving image retrieval requests.

A Sun 4/490 server computer (Sun Microsystems, Mountain View, CA) is used as the data management engine. With an advanced input/output design between the central processing unit (CPU) and the 32-Mbyte cache memory, this computer can perform 22 million instructions per second. Managing a large amount of patients' imaging data requires not only a powerful CPU but a fast image buffer to store the data. Four intelligent peripheral interface (IPI) magnetic disks (4 gigabytes) serve as the fast-access buffer to store and retrieve patients' image files. The read/write performance of the IPI disk is approximately 3.4 Mbyte/sec.

A Kodak automated optical disk library (ADL) 6800B (Kodak, Rochester, NY) is used as a long-term image archival and retrieval device. The ADL is connected to the Sun computer through a small computer system interface and an RS-232 interface port. The ADL was chosen to serve as the long-term storage component because of the following features: large capacity (680 gigabytes), acceptable data-transfer rate, and remote archival and retrieval capability.

Display Subsystem

The display workstation used for this evaluation is based on a Sun-Pixar image computer. The major hardware components of this display workstation include a Sun 3/260 minicomputer, a Pixar II 1K image processor (Pixar, San Rafael, CA), and four VMI (Eau Claire, WI) 1280 × 1024 progressive video monitors. Two storage module drive magnetic disks with 1.4 gigabytes are used for the fast-access patients' images. A mouse, a mouse pad, a keyboard, and a console (text) monitor allow users to access the display subsystem. The image display time for a full screen from the disk to a display monitor is about 7–10 sec. The response time of the image display functions (e.g., window-and-level, zoom-and-scroll, and cine loop [2, 3]) is instantaneous.

Data Base

Table 1 shows the number of examinations of patients and image files acquired in the neuroradiology PACS module from

TABLE 1: Numbers of Patients' Examinations and Image Files Collected in the Neuroradiology Picture Archiving and Communication System Data Base from February 1, 1990, to July 31, 1991

Imaging Technique	No. of Examinations	No. of Studies	No. of Gigabytes
CT	4,984	9,233	101
MR	4,321	19,234	39
Total	9,305	28,467	140

Note.—The number of studies is equivalent to the number of image files.

February 1990 through July 1991. There were 4984 CT and 4321 MR examinations; these examinations include 9233 CT and 19,234 MR image files (studies). In terms of digital storage capacity, 140 gigabytes was used. All these data were archived to the Kodak ADL, serving as the long-term image archive.

Evaluations and Results

Image Delivery Performance

To compare image delivery performance between the film management system and the neuroradiology PACS, we divided both operating systems into four comparable stages [4, 5]. For the film management system: (1) technologists at each CT and MR scanner create films by windowing images, printing images, and developing films; (2) film librarians deliver the developed films to the neuroradiology administration office; (3) neuroradiology clerks retrieve the patient's historical films and combine them with the current examination films; and (4) radiology residents or film-library personnel pick up the prepared films and deliver them to a readout area.

Similarly, the four stages in the PACS are (1) the period that the capture computer receives images from the scanner systems and formats images into a standard image file, (2) the elapsed time of transferring image files from the capture computer to the data management host computer, (3) the processing time for managing and retrieving image files at the data management host computer, and (4) the time for distributing image files from the data management computer to the display workstation.

The time spent in each film management stage was timed and estimated by several technologists, film clerks, and personnel who have many years of professional experience. Some circumstances were excluded from the calculation because their performance variances are too large to be valid. These include retrieving a patient's historical films from the film warehouse (approximately 6½ km away) and the lag time between pickup and delivery of films to and from the various stages in the film management system described previously. These exclusions apparently make the film-based management system more competitive in the performance comparison with the PACS module.

The performance of the data management subsystem in PACS was automatically recorded in data-base files and log files by the software modules. The data included in these files

are (1) date, time, and duration of each modularized process and (2) size of image file acquired.

The total elapsed time from when an image file is created at a scanner to when the image file is available at a display workstation is defined as the image delivery performance of a PACS system. Table 2 shows the results of average image delivery performance for one currently acquired image file from the scanner and one archived image file from the Kodak ADL. CT and MR image files are quite different in size. On average, a CT file is approximately five times larger than an MR file [6]. Because the image file size is one of the fundamental factors affecting the delivery performance, CT and MR image files were recorded individually.

Table 3 shows the performance comparison of image delivery between the film management system and the neuroradiology PACS module. As a consistent comparison baseline is difficult to achieve for both systems, the performance (time to complete tasks in each stage) was based on a patient's film jacket in the film-based management system and the patient's two examinations in the PACS system. On average, approximately two image files (studies) were created for each CT examination and five image files were generated in an MR examination [6]. The two CT image files are either unen-

hanced or enhanced studies, or one of them is a scout view image. The five MR files are studies with various pulse sequences. Therefore, in this comparison study, we used two newly acquired and two previous CT image files and five newly acquired and five previous MR image files as a basis in the digital system. In general, the average image delivery performance (88.5 min for CT and 44.2 min for MR) of the PACS system is better than the average performance (93 min) of the film-based management system. However, a patient's film jacket can contain many image examinations. If more than two examinations were used to calculate the image delivery performance with the PACS system, the result of the comparison study could be different. It must be noted that although all historical examinations of a patient are important, the latest previous examination is essential in a clinical comparison study. Most neuroradiologists in our department use the current image examination and the latest previous examination to make the diagnosis and refer to older examinations only when it is necessary.

In the PACS system, the performance of delivering one MR examination (five image files) is twice as fast as that of delivering one CT examination (two image files). The major difference is at stage 1: 80 min are required to capture and format images for a CT examination but only 35 min are required for an MR examination. The performance bottleneck is not in the twin processes of capturing and formatting in the PACS but in the system design of the GE 9800 CT scanner, which causes a lengthy delay. This scanner has no means of indicating to the communication protocol that the last image slice of a given study in the CT image acquisition process has been sent. Thus, the image capturing program has to wait until the first image slice of the next study is received before it closes the last image file. This implies that any performance improvement of delivering CT examinations will be of limited success until the system design of the GE 9800 CT scanner is modified.

TABLE 2: Analysis of Image File Delivery Performance of the Neuroradiology Picture Archiving and Communication System Module

File	No. of Minutes				
	Stage 1	Stage 2	Stage 3	Stage 4	Total
CT					
Current	40.0	0.50	0.15	1.15	41.80
Previous	0	0	1.25	1.15	2.40
MR					
Current	7.0	0.15	0.17	0.47	7.79
Previous	0	0	0.57	0.47	1.04

Note.—Current image file is newly acquired from the imaging scanner; previous image file is previously acquired and archived to the Kodak automated optical disk library.

TABLE 3: Comparison of Image Delivery Performance Between the Film Management System and the CT/MR Picture Archiving and Communication System Module

System	No. of Minutes				
	Stage 1	Stage 2	Stage 3	Stage 4	Total
Film-based system					
Optimal situation	25.0	1.0	2.0	0	28.0
Regular situation	50.0	25.0	15.0	3.0	93.0
Picture archiving and communication system					
CT	80.0	1.0	2.9	4.6	88.5
MR	35.0	0.75	3.75	4.7	44.2

Note.—The optimal scenario takes place only when a patient has no previous radiographs, only a few images are obtained, and the patient's images are reviewed in a film reading room near the scanner and the film administration office. For CT, two newly acquired and two previous CT image files were used to calculate the total. For MR, five newly acquired and five previous MR image files were used to calculate the total.

System Availability

The PACS system availability was examined in terms of the probability of each component being functional during the period of evaluation. The components considered to affect the availability of the neuroradiology PACS include (1) the image acquisition subsystem, with its three GE 9800 CT scanners and three GE Signa MR scanners, capture computers (two Sun 4/370, one Sun 3/60, and one Sun 4/390), and interface devices between the scanners and the capture computer (ACR/NEMA interface boards and Ethernet boards); (2) the data management subsystem, which includes the data management computer system (Sun 4/490) and the Kodak optical disk library (ADL); (3) the display subsystem, with its display workstation computer system (Sun 3/260), Pixar image computer, and display monitors; and (4) the Ethernet communication network.

We selected 2 months during the midpoint of this evaluation study, from December 1, 1990, to January 31, 1991, to record the downtime of each component (excluding the CT and MR scanners). During this 2-month observation, the leading

TABLE 4: Number of Component Failures and Shutdowns Recorded Between December 1, 1990, and January 31, 1991

Causes of Downtime	Components						Total
	Data Management Computer System	Optical Disk Library	Display Computer System	Pixar Image Computer	Display Monitors	Ethernet Network	
Electrical or mechanical malfunction	1	4	0	0	0	0	5
Power failure	0	0	0	0	0	0	0
Human error	0	0	0	0	0	2	2
Scheduled maintenance							
Hospital power shutdown	6	6	1	1	1	0	15
System repair service	1	4	0	0	0	0	5
Service-related shutdown	4	0	0	0	0	0	4
System integration	2	0	0	0	0	0	2
Total	14	14	1	1	1	2	33

causes of component unavailability such as electrical and mechanical malfunctioning, power failure, human error, and scheduled shutdowns were recorded and analyzed. The scheduled shutdowns included hospital power shutdown tests, scheduled maintenance of components, repair service-related shutdowns, and system integration or upgrade. In order to minimize the system's unavailability, these necessary component shutdowns were scheduled, whenever possible, at times when the PACS system had the least activity, such as nights and weekends. (These occurrences were counted as contributing to the system's unavailability.) Table 4 details the component failure and shutdown records for the causes described here. Excluding the scanners, the data management computer system and the Kodak ADL shut down the most often (14 events for each system). However, only five occurrences (one occurrence for the data management computer and four for the ADL) can be directly attributed to the system's unreliability; the rest were due to scheduled preventive maintenance events.

In calculating the probability of each component being functional, we used the 24-hr daily operating time as a basis. Table 5 summarizes each subsystem's availability, which was calculated by multiplying each component's uptime probability in the subsystem defined as follows:

$$P = \prod_{i=1}^n P_i$$

where P_i is the uptime probability of each component and n is the total number of components in the subsystem [7]. The results of each subsystem availability were as follows: 92.73% for the image acquisition subsystem, 95.32% for the data management subsystem, 99.97% for the display workstation, and 99.92% for the Ethernet communication network.

If a neuroradiologist wishes to use the display workstation to study recently examined and archived images, all components must be available. The total system uptime is the product of each component's uptime probability, which was 88.29%. Viewing newly acquired images required all components but the Kodak ADL to be available; the system had a 92.13% uptime probability. The system's uptime probability for viewing archived images was 95.22% (the image acquisition subsystem was excluded). If the desired patient's case existed in the display workstation, the system could provide the neuroradiologist with a 99.97% chance of reviewing this patient's images.

TABLE 5: Uptime Percentages of Individual Components

Components	% Uptime
Image acquisition subsystem	
Three MR scanners (P1 × P2 × P3)	98.00
Two MR capture computer systems (P4 × P5)	99.98
Three CT scanners (P6 × P7 × P8)	97.67
Two CT capture computer systems (P9 × P10)	99.90
Two GE data links (scanner to capture computer interfaces) (P11 × P12)	97.00
P1 × P2 × P3 × ... P10 × P11 × P12	92.73
Data management subsystem	
Image archival computer systems (P13)	99.47
Kodak automated optical disk library (P14)	95.83
P13 × P14	95.32
Image display subsystem	
Display workstation computer systems (P15)	99.99
PIXAR image processor (P16)	99.99
Display monitors (P17)	99.99
P15 × P16 × P17	99.97
Communication network	
Ethernet network (P18)	99.92

Note.—The period of observation was from December 1990 through January 1991. P1, P2, P3, ..., P17, and P18 are the uptime probabilities of individual components.

tion subsystem was excluded). If the desired patient's case existed in the display workstation, the system could provide the neuroradiologist with a 99.97% chance of reviewing this patient's images.

User Acceptance

We evaluated the acceptability of the display workstation by observing its use, surveying users' responses, and conducting a preliminary image quality study.

Table 6 shows the total number of viewing sessions conducted in the display workstation between July 1, 1990, and July 31, 1991. A digital image viewing session is the period of time when radiologists interact with a set of image files belonging to a given patient through an electronic display system [8]. Here, we divided an image viewing session into three interactions: patient selection, image file display, and

TABLE 6: Number of Viewing Sessions Conducted in the Display Workstation Between July 1, 1990, and July 31, 1991

Viewing Sessions	No. of Occurrences
Patient selection	3721
Image file display	8920
Image manipulation function	2221

image manipulation. The functions of image manipulation include window-and-level, contrast-and-brightness presetting, image enlargement, zoom-and-scroll, image arrangement, image frame exchange, and cine viewing [2]. There were 3721 viewing sessions conducted with the display workstation. Among these viewing sessions (Table 6), 8960 image files were reviewed and 2221 manipulation functions were used.

Ten users of the display workstation were invited to rate it on the following performance attributes: image quality, speed of image display, convenience of image layout, performance of manipulation functions, sufficiency of patient information, sufficiency of image parameters, ease of use, and overall impression. A four-point rating scale was used in this survey that includes response choices of poor (1 point), fair (2 points), good (3 points), and excellent (4 points) [9]. The surveyed users included neuroradiology staff, fellows, residents, and visiting scholars who had some familiarity with the system. The results of the survey are summarized in Table 7. The overall score was 3.4 on the four-point scale.

Two neuroradiology faculty and one fellow conducted a preliminary study to compare cross-sectional image quality on the films and on the display monitors. Each neuroradiologist randomly selected 10 cases during daily image-reading rounds. The digital images were displayed on the display workstation, and the corresponding films were arranged at an alternator. A ranking scale (1–6) was provided to grade both the film and CRT systems according to the radiologist's confidence in the finding (1 for least confidence and 6 for most confidence). In total, eight CT cases and two MR cases were used in this study. The lesion and disease findings included lymphoma of the thyroid gland, dural leukemia, thyroid goiter, submandibular adenopathy, duct stone, fracture

of the cervical spine, and cancer of the tongue. The results indicate that the cross-sectional images printed on the films and those displayed on the CRTs have essentially equivalent image quality for review (Table 8). In addition, the results regarding image quality (3.8 on a four-point scale) in the user survey response also indicated that the image quality on the digital display monitors is acceptable (see Table 7).

Discussion and Conclusions

The results of this evaluation show that the neuroradiology PACS module is fully functional. The PACS is clinically useful in several ways: (1) the remote viewing capability can save radiologists' time in walking between distant buildings, (2) automatic image management ensures that the images are archived properly, and (3) the fast image retrieval services can deliver a patient's archived examination in a timely manner (2 min on the average).

Responses from the display workstation acceptance survey indicated insufficient information on the patients' demographics and image scan parameters (Table 7). An ongoing effort has been the decoding of the ACR/NEMA formatted data by the image acquisition programs. The revised software programs will undoubtedly provide more sufficient information.

The long-term image storage device (Kodak ADL) and the interface devices between the CT scanners and the capture computers were found to be the two least reliable hardware components (95.83% and 97% uptime, respectively). The major cause of the ADL downtime was the suboptimal operating environment. Its uptime improved after the ADL was relocated to a new computer room with improved environmental specifications. In addition, a remote diagnostic feature, which enables the Kodak engineers to directly inspect the ADL through a telephone line, has been implemented. When the ADL is malfunctioning, this feature allows the Kodak engineers to suggest appropriate repair procedures to the local service personnel. Consequently, the downtime of the ADL has been minimized. With regard to the reliability of the CT image acquisition interface, the current interface is only a temporary solution to the problem of automated image acquisition. The updated GE CT scanner does not require the intermediate interface devices to receive images. Instead, the

TABLE 7: Results of Display Workstation User Survey

Attribute	Score				Average Score
	Poor (1)	Fair (2)	Good (3)	Excellent (4)	
Image quality			2	8	3.8
Speed of image display			3	7	3.7
Convenience of image layout		1	8	1	3.0
Performance of manipulation functions			5	5	3.5
Sufficiency of patient information		4	3	3	2.9
Sufficiency of image parameters	1	2	4	3	2.9
Ease of use			2	8	3.8
Overall impression			3	7	3.7
Overall average					3.4

Note.—These scores are based on the evaluations of 10 users.

TABLE 8: Results of Preliminary Image Quality Study Comparing Film and Light Box vs the Display Workstation

Ranking Scale	Film and Light Box	Display Workstation
1 (least confidence)	0	0
2	0	0
3	0	0
4	0	0
5	5	4
6 (most confidence)	5	6

Note.—The image quality in 10 randomly selected cases (eight CT, two MR) was evaluated by three neuroradiologists. The ranking scale is based on the interpreter's degree of confidence in the finding.

new CT scanner allows direct connection to the PACS system via the Ethernet protocol and has full capability to serve both the scanning task and the image transfer simultaneously. Thus, the unreliability issue on the CT image acquisition interface was substantially diminished after we upgraded three scanners to the GE Highlight Advantage CT unit.

On the basis of the results of this study, we have designed and implemented the infrastructure of PACS for our department [10]. This infrastructure emphasizes the system's connectivity, speed of image delivery, and reliability of the complete PACS. The major component failures in the current system, including electrical and mechanical malfunction, power shutdown, system repair, and service-related shutdown, are minimized in the infrastructure. A higher speed communication network is used to improve image delivery performance [11]. In addition, a second generation of display workstations that can display images in 1–2 sec for a 2K × 2K × 16 bit image has been designed and is being clinically evaluated [12–14]. We are in the process of collecting new data based on these improvements.

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Computers in Radiology

Integration of a Personal Computer Workstation and Radiology Information System for Obstetric Sonography

Mark S. Frank,¹ David W. Green, Julie A. Sasewich, and Janet A. Johnson

A personal computer workstation has been developed for storage and analysis of obstetric sonographic examinations. The workstation also serves as an interactive data terminal for our radiology information system. A data-base management program locally stores quantitative and descriptive sonographic results. Algorithms are used to analyze growth parameters over serial examinations, plot growth curves, generate a radiologic report, and provide instantaneous diagnostic assistance and suggestions. A bibliographic data-base system containing more than 3000 references (with abstracts) in the obstetric sonographic literature is integrated with the software's analytical functions. A telecommunications software module performs dialogues, such as immediate automatic transcription of the sonographic report, with the radiology information system. An examination summary form, growth curves, and the radiologist's report can be printed or digitally faxed by the workstation after authorization by the radiologist.

The workstation has improved the organization of sonographic data, facilitated serial quantitative analysis, supplemented educational resources for our staff radiologists and residents, reduced transcription errors and transcription delays, and shortened to minutes the time necessary to deliver precise examination results to clinicians. This model is suitable for use in many areas in a radiology department.

Radiology departments generate and manage diverse information, yet historically radiology information systems have maintained a centralized set of data bases that constrain both the detail of stored information and the capability to manipulate or analyze it. We have integrated an inexpensive personal

computer workstation with an established commercial radiology information system for use in obstetric sonography to emulate a "next generation" radiology information system and provide (1) more powerful local information storage, analysis, and communication; (2) full radiology information system access and functionality; and (3) educational and diagnostic assistance for staff radiologists, residents, and technologists.

Configuration and Operation of the Personal Computer Workstation

A VAX 11/785 minicomputer system and DECrad (Digital Equipment Corp., Maynard, MA) make up the hardware and software platforms of our radiology information system. An 80386 CPU-based IBM-compatible personal computer operating under MS-DOS 5.0 serves as the workstation. The machine contains a 125-megabyte hard disk and an Intel SatisFaxion fax card (Intel Systems, Hillsboro, OR). A 1024 × 768 pixel color VGA (video graphics array) monitor provides text and graphics display. A Hewlett-Packard LaserJet IIIp printer provides hard-copy output. The workstation serves as a DECrad terminal and is connected to DECrad with a 19.2-kilobaud RS-232 serial interface. The Foxpro data-base programming language (Microsoft Corp., Redmond, WA) has a mouse-driven, window-oriented user interface for data management and analysis. High-resolution graphics are displayed and printed with a software "add-in" for Foxpro called dGE (Pinnacle Publishing, Federal Way, WA). DEC terminal emu-

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lation (VT-220) and automated dialogues with DECrad are performed with Crosstalk Mark IV telecommunications software (DCA Associates, Alpharetta, GA).

The software was designed as four intercommunicating modules, providing, respectively (1) management and analysis of obstetric sonographic examinations, (2) interactive diagnostic assistance, (3) immediate access to an obstetric sonographic literature data base containing references since 1980, and (4) radiology information system connectivity. The user can switch among them with a single keystroke. Information can be transferred within or among the modules by using a virtual "clipboard" concept. Wherever possible, a "point and shoot" method is used with a mouse for entering information or telling the computer what to do next. A computerized telephone book containing fax numbers for our referring clinics is maintained within the obstetric sonographic module. Requests for examinations are faxed from these clinics directly to our workstation.

Three windows of data are entered for each obstetric sonographic examination: (1) patient identification with demographic information and clinical history; (2) information regarding the survey of fetal anatomy, uterus, placenta, and parametrial structures; and (3) quantitative information obtained from measurements taken on sonographic images (Table 1). The software maintains a superset of criteria specified in the standards for prenatal sonographic examination as submitted by the American Institute of Ultrasound in Medicine.

The sonographer enters descriptive information via mouse-driven selections from on-screen lists and check boxes. This type of data entry is adequate for approximately 85% of our examinations. When needed, pop-up windows allow input of freeform text on patient history, placenta, parametrial structures, and conclusions (typically entered by the radiologist). These data, with quantitative results based on previous examinations or last menstrual period, are used to generate a sonographic report of virtually any complexity. Algorithms construct complete sentences to simulate a "spoken" dictation rather than obvious computer-generated text. The report can be edited by using a built-in word processor and then faxed, printed, or uploaded to the radiology information system for the patient's permanent record. A data sheet containing information similar to the report's but in a more structured format (Fig. 1) can also be faxed or printed. Single and multigestation pregnancies can be processed.

The computer recognizes follow-up visits and copies appropriate information from previous examinations, updating temporally changing data such as projections for estimated gestational age and fetal weight. Look-up tables generated from regression equations [1] are used to assign an estimated gestational age for each biometric value (or vice versa). The computer calculates biometric ratios (femur length vs biparietal diameter, femur length vs abdominal circumference, and head circumference vs abdominal circumference), estimates fetal weight, and compares results with published norms [2, 3]. All calculated numbers are immediately updated on-screen whenever a biometric parameter is entered or changed.

The workstation instantly provides an on-screen tabular history of fetal growth (biparietal diameter, head circumfer-

TABLE 1: Data Maintained by Obstetric Sonography Module

General data
Patient's name
Date of examination
Patient's birthday
Examination number
Medical record number
Date of last menstrual period
Obstetrician
Indications for examination
Clinical comments ^a
Date/estimated gestational age at previous examinations
Sonographer
Radiologist
Concluding comments ^a
Computed values
Estimated gestational ages for all biometrics
Fetal weight
Last menstrual period and estimated date of confinement
Biometric ratios
Femur length: biparietal diameter
Femur length: abdominal circumference
Head circumference: abdominal circumference
Fetal survey
Fetal count
Fetal position
Fetal motion
Amniotic fluid volume
Position of placenta
Placental grade
Extent of previa
Placental lucencies
Placenta comments ^a
Adnexal cysts
Uterine masses
Parametrial comments ^a
Fetal anatomy
Cerebral ventricles
Posterior fossa
Heart
Stomach
Kidneys
Bladder
Spine
Cord insertion
Biometrics
Biparietal diameter
Occipital frontal diameter
Head circumference
Abdominal circumference
Femur length
Crown-rump length
Mean gestational sac size
Visualization of:
Distal femoral epiphysis
Proximal tibial epiphysis
Proximal humeral epiphysis
Miscellaneous data
Interesting case comments ^a
Log of faxes sent
Log of reports transferred to radiology information system

^a A freeform typed response can be given to this item.

ence, abdominal circumference, femur length) spanning several examinations, displaying predictions for each biometric parameter in millimeters and "weeks of growth" accompanied by deviations from the predictions. Growth curves derived from biparietal diameter, abdominal circumference, femur

Fig. 1.—Example of computer-generated data sheet summarizing examination results. Freeform comments about clinical history, placenta, and conclusions are included. MRN = medical record number, LMP = last menstrual period, HTN = hypertension, AFP = alpha-fetoprotein, EGA = estimated gestational age, EDC = estimated date of confinement, MSD = mean sac diameter, CRL = crown-rump length, BPD = biparietal diameter, HC = head circumference, AC = abdominal circumference, FL = femur length; DFE, PTE, and PHE refer to visualization of distal femoral, proximal tibial, and proximal humeral epiphyses, respectively.

Exam
Date: 05/24/92

OBSTETRICAL ULTRASOUND DATA SHEET

CLINICAL INFORMATION
Pt: DOE, JANE Q. Age: 31 MRN: 4667887 LMP: 10/01/91 --> 33.7 wks
Clinical: Dates XX Growth Pain Bleed HTN Diabetes AFP
Previous - EGA
12/15/91-10.9 wks. EDC 07/07/92 Physician: WATTS
02/19/92-20.3
03/23/92-24.3 Comment: Maternal Lupus.
Expected-33.9

GESTATION: Single POSITION: Vertex AMNIOTIC FLUID: Normal
MOVEMENT: XX Heart Trunk XX Extremity Diaphragm

PLACENTA
XX Anterior Post. Fundal Left Right LowerSeg
LUCENCIES: Preplacental XX Internal Retro Subchorionic
GRADE: 1 PREVIA: None Fibroids L. Adn Cyst R. Adn Cyst
Comments: Intraplacental lucencies are compatible with placental lakes.

BIOMETRICS
MSD: mm --> wks HC/AC: OK FL/AC: OK FL/BPD: OK
CRL: --> wks DFE PTE PHE
BPD: 82 --> 33.0 wks
HC: 307 --> 33.8 wks
AC: 294 --> 33.5 wks
FL: 64 --> 32.8 wks
EGA: 33.3 wks +/- 2.3 wks
Estimate Fetal Wght: 2015 grams
Expected Fetal Wght: 2131 grams

FETAL ANATOMY
NL Ventricles NL Spine NL 4-Ch-Heart NL Stomach NL Cord
NL Kidneys NL Bladder NS Post. Fossa
NL = Normal TE = Too Early NS = Not Seen (Obscured) ** = Abnormal

COMMENTS: Cord Doppler Ratio: 2.5 -- within normal limits.

Sonographer: JAS

Radiologist: RDC

length, and estimated fetal weight for each examination can be displayed, printed, or faxed in a "four-on-one" format (Fig. 2). Facsimile transmission occurs as a background task, freeing the computer for ongoing use.

Other miscellaneous features of the software include an on-screen calculator, a calendar/reminder system, and a computerized version of the traditional obstetric "date wheel." The computer prints a summary of examinations each day. This hard-copy record is appended to our loose-leaf obstetric sonography logbook.

Access to our radiology information system has "interactive" and "automatic" modes. When the user desires interactive dialogue with the radiology information system, a single keystroke switches between the obstetric sonography system and DECrad terminal emulation. Automated dialogues perform specific tasks such as transfer of the computer-generated sonographic reports to the radiology information system and transfer of reports (not limited to sonography) from the radiology information system to the workstation for maintenance of teaching files and case lists for clinical studies or quality-assurance procedures.

We have implemented several internal consistency checks. The computer will flag illogical measurements or temporally impossible conditions. Transfer of information via fax, hard copy, or radiology information system connectivity is prohibited on examinations with incomplete data. Our sonographers compare estimated gestational age on hard-copy images with those calculated by the computer as an ongoing quality-assurance project. Transfer of sonographic reports from workstation to DECrad is rigorously monitored; date and time of the transfer, plus any failures, are logged. The patient's medical record number, examination identification number, and type of examination must be identical on both systems or the transfer is aborted for that patient. The computer-generated report must still be electronically signed on the radiology information system before it becomes part of the medical record.

A hierarchical diagnostic help module is integrated with the obstetric sonographic software and invoked with a "hot key." For any given topic selected by the user, informative text and tables and a pop-up list of related topics are presented. Selecting a related topic results in an instant jump to infor-

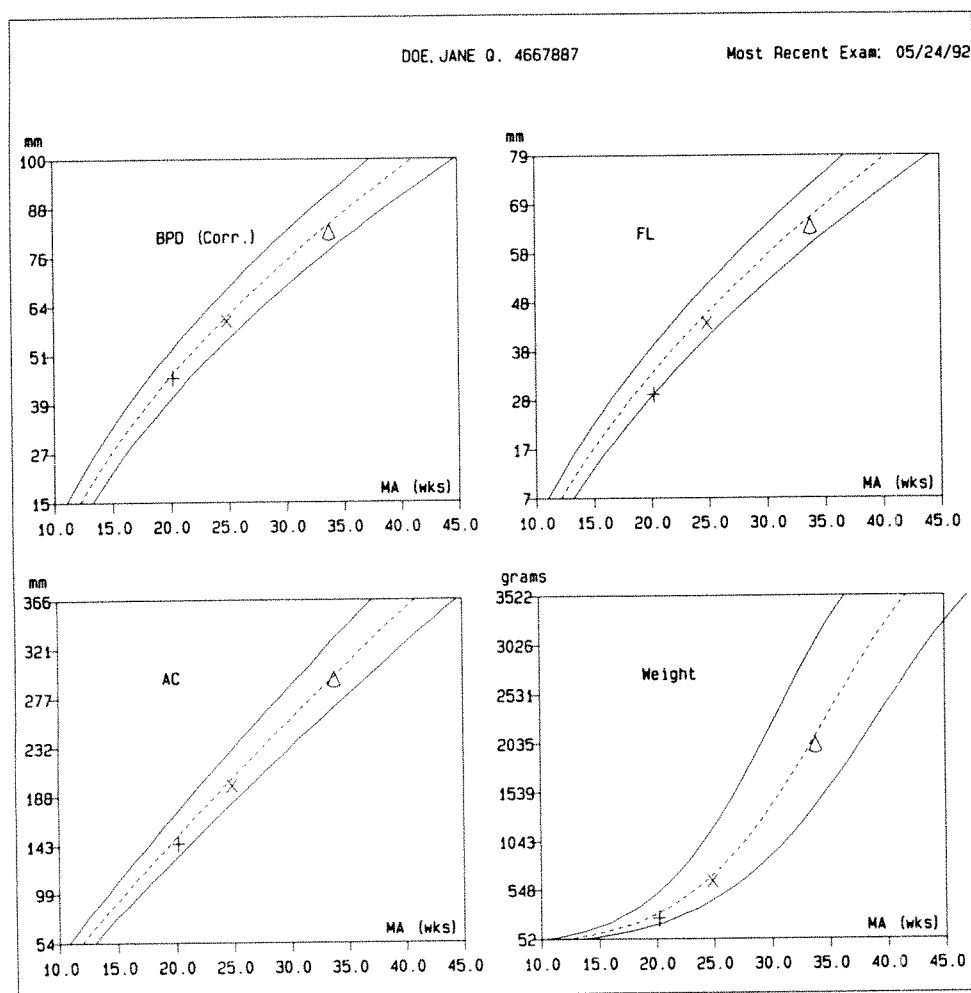


Fig. 2.—Example of four-on-one computer-generated growth curves for a patient undergoing third examination. BPD (Corr.) = biparietal diameter corrected with occipital-frontal diameter, MA = estimated gestational age beginning with last menstrual period, FL = femur length, AC = abdominal circumference.

mation on that topic, with a new pop-up list of related subjects, including a backward link to the previous one. Any displayed information may be copied into the sonographic report with a cut-and-paste technique by using the virtual clipboard. The help system is frequently updated by using a special code for "modify" access. A bibliographic data base containing over 3000 obstetric sonographic references may also be accessed with a single keystroke. Items stored for each reference include authors, title, source, key words, and abstract. Complex queries can be performed. A subset of references can be included in the radiologist's report, printed according to the user's formatting specifications, or copied to a new data base.

Discussion

Improved patient care is delivered through several mechanisms. Fast, detailed, and accurate quantitative analysis of fetal growth frees radiologists and sonographers to spend more time thinking and less on tedious tasks. Detailed results from previous examinations are instantly accessible for any patient. Analysis spanning several examinations is available in graphical or tabular formats that can be digitally faxed on completion of the examination, providing radiologists and clinicians a broader, better organized overview of the patient.

Clinicians also benefit from receiving consistent, well-organized reports. The workstation uses a more powerful and uniform method for storing and reporting examination results compared with the traditional voice dictation and handwritten logbook methods. Standardized biometric analysis alleviates deviations encountered when scanning is done on machines with different look-up tables. The diagnostic help system and bibliography data base supplement the radiologist's working knowledge. Elusive dictation errors (e.g., transposing numbers, saying an incorrect estimated gestational age for a correct measurement) and problems with legibility of handwritten forms are eliminated. Transcription errors are drastically reduced.

The radiologists' and sonographers' time is used more efficiently. Virtually all manual calculations and redundant tasks are eliminated. Education is more easily integrated with daily practice through immediate access to diagnostic assistance and clinical literature. Faster patient throughput enables treatment of more patients and more cost-effective care. Digital faxing saves paper by eliminating the need for additional printouts. If the radiology information system sustains a failure and loses information, the workstation can regenerate and retransmit reports.

Computerized reporting exists in parallel with traditional dictation. The computer-generated report, with no freeform

text added by a radiologist, is sufficient for approximately 90% of our patients. With a particularly complicated case the radiologist may forgo the computer-generated report and dictate by voice. This is rare (less than 1%), but most of our patients are seen for screening examinations rather than high-risk pregnancies. The likelihood that a radiologist will use the freeform text windows rather than processing complicated examinations by voice seems more dependent on typing skills than on the complexity of the report. However, as the results of all examinations are stored on the computer, the many benefits from computer-assisted reporting almost always outweigh the inconvenience of typing the one or two sentences necessary to conclude an intricate report.

Users of the system have been informally surveyed. The sonographers have appreciated the drastic reduction in time necessary to prepare information for the radiologists. Consequently, they are willing to train even our less computer-savvy radiologists to use the system. Radiologists have unanimously indicated that their time is used more efficiently by computer-assisted reporting and by the capability to quickly access and analyze data spanning several examinations. Residents have expressed enthusiasm about on-line diagnostic assistance, particularly when assembling a differential diagnosis. There is variability in individual methods of operation. Some radiologists prefer to review hard-copy images after several examinations have been completed before generating reports. Networking the existing workstation in the sonography suite with another workstation in the reading room could simplify this method. In order to minimize the delay between completion of the examination and distribution of the results, other radiologists prefer to complete their report immediately

after seeing the patient and reviewing the sonographer's findings.

Disciplines with well-encapsulated diagnostic considerations (e.g., obstetric sonography, mammography) have been particularly amenable to computer-assisted reporting [4, 5]. Initially these were stand-alone computer systems with relatively isolated data bases. More recently, interfacing with existing hospital systems has been described [6, 7]. Future radiology information systems (and health care systems in general) will gradually incorporate more sophisticated algorithms for education and diagnosis. We have used existing technology to prototype some of these features.

Readers who want more information about the availability of the sonographic software may contact the authors.

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Book Review

"The President Has Been Shot." Confusion, Disability, and the 25th Amendment in the Aftermath of the Attempted Assassination of Ronald Reagan. By Herbert L. Abrams. New York: Norton, 363 pp., 1992. \$22.95

A central tenet of democracy in the United States is that trust by the people and responsibility for their protection and governance is assigned to duly elected and responsible individuals. The capacities of these individuals to deserve this trust and fulfill such responsibilities are, of course, not inviolable. In the modern world, it has become necessary to provide prompt and appropriate continuity and succession for leadership. The 25th Amendment to the Constitution, ratified in 1967, provides channels whereby smooth temporary succession to *acting presidency* by the Vice President can be effected when the President notifies congressional authorities that he is or will be "unable to discharge the powers and duties of his office." The President can recover presidential authority by properly attesting that he has recovered his capabilities. The 25th Amendment takes into account that the President may be unaware or incapable of initiating such a transfer. In this event, the Vice President and a majority of the cabinet or such other body as the Congress may by law provide, can initiate appropriate transfer of power and authority.

This book is a well-documented, conscientious analysis of presidential disability and constitutional succession by the eminent radiologist, Herbert L. Abrams. It establishes that during the aftermath of the attempted assassination of President Ronald Reagan shortly after his administration came to power, certain appointed officials in the White House and cabinet gathered unto themselves formal and informal presidential powers and authority at a time when the 25th Amendment should have been invoked to enable Vice President George Bush to serve as acting President. This failure of constitutional responsibility affected the entire period while President Reagan was intermittently and prolongedly incapable of understanding complicated issues and of making critical decisions. During the period of Reagan's wounding, anesthesia, major surgery, and convalescence, members of the White House staff *"were the president of the United States"*. They were not elected officials, nor were their appointments subject to the review and approval of the Congress."

Baker, Meese, and Deaver, among others, deliberately fostered confidence among elected officials and the general public that Reagan was consistently and competently responsible for the U.S. governmental and presidential decision making throughout the aftermath of that attempted assassination. White House staff members, Vice President Bush, and members of the Reagan cabinet did not invoke or apparently seriously deliberate invoking the 25th Amendment, which was their constitutional responsibility. At no time during this life-threatening event and its aftermath, which extended several weeks, was Vice President Bush given formal responsibility and authority to act on behalf of the President in respect to military, domestic, or foreign affairs. Indeed, between the time of election in November until assassination bullets were fired by John Hinckley 4 months later, the Reagan-Bush team failed to give appropriate consideration to what would be—or in point of historical fact, what became—their legal and constitutional responsibility to arrange for

temporary and possibly longer lasting relinquishment of presidential leadership.

Considerable confusion and uncertainty existed among members of the White House staff and the cabinet about their responsibility for ensuring appropriate succession. Mandated options were not formally considered by the transition team, and the relevant documents were physically removed from cabinet review (by Darman, authorized by Baker) at the outset of this serious and relatively prolonged emergency. This episode illuminates an overarching threat to continuity of democratic process, as Abrams documents, inasmuch as illness or other disabling experiences have affected nearly every U.S. President in this century.

It is not as though members of the new Reagan administration were without domestic and international challenges at the time of the assassination attempt and throughout its aftermath, challenges that required competent presidential leadership and critical decision making. Indeed, the Soviet Union was massing its troops menacingly along the borders of Poland and threatened to seize military control of that country if Soviet alarm over Polish governmental accommodations to Solidarity was not assuaged. Other foreign, domestic, and legislative programs and decisions were being authorized by appointed officials without duly considered presidential supervision, analysis, and approval.

Abrams is an authority on the subject of disability among political leaders. In this careful analysis, he provides detailed chronologic evidence from a variety of vantage points among medical and political witnesses relating how President Reagan was treated and how he responded throughout the course of the assault, hospitalization, emergency surgery, and recovery. For instance, the President required seven units of replacement blood and had abdominal lavage as well as prolonged surgical exploration of his bleeding left lung. Abrams provides evidence relating to Reagan's mental state and capacity to meet presidential responsibilities throughout his gradual recovery. Reagan was visibly weak and feeble for several weeks and did not feel subjectively well for 6 months.

Abrams presents extraordinarily constructive and thoughtful guidelines for future administrations, vis-à-vis their obligations respecting the 25th Amendment, and for appropriate functional relations and responsibilities that should be assumed by the President's physician and White House medical personnel. The book is up-to-date in showing that some of these problems are now being addressed more openly and adequately. It makes overwhelmingly obvious the fact that our government cannot operate democratically and safely in the global arena without seamless continuity and focused responsibilities borne by elected officials.

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Perspective

To Telephone or Not to Telephone: How High Is the Standard?

Leonard Berlin¹

*How deep is the ocean
How high is the sky
How much do I love you
I'll tell you no lie.*

—Irving Berlin, "How Deep Is the Ocean"

The Case

No one ever questioned the good intent of the Missouri hospital's management or its radiologists when they decided to undertake a breast cancer screening program for the hospital's female employees in January 1988, but, as we shall see, a malpractice lawsuit filed as a result of the program led to a costly indictment of the manner in which they implemented it. The hospital contracted with a mobile diagnostic imaging company to supply a fully equipped and staffed mammography unit that would be stationed on a given day at the hospital, obtain and develop appropriate film-screen mammograms, and present the breast radiographs to the hospital's radiologists for interpretation. As part of its registration and record-keeping procedures, the mobile company provided a form on which the patients would be asked to fill in certain demographic and historical data, along with the name of a physician to whom the mammographic report should be sent. On January 6, 1988, a 40-year-old female nurse employed by the hospital registered for the mammo-

graphic examination, filling out the appropriate form and indicating as recipient-to-be the name and address of a physician who happened to be a family practitioner for whom the nurse had previously worked, and to whom she had previously gone for occasional medical care. Her mammogram was completed, and later that day was interpreted by a hospital radiologist as showing "an ovoid lesion" in the right breast for which "further evaluation" was indicated. The hospital staff mailed the radiology report to the family physician, and thereafter had no further communication with the nurse about her mammographic findings.

There was no contact, either by telephone or in person, between the nurse and her family doctor or his office personnel until 14 months later, when, in March 1989, the nurse visited the physician in his office because she felt a lump in her right breast. During the doctor's examination of the nurse, in which he confirmed the presence of a mass in the breast that required biopsy, he noticed that the January 1988 mammographic report was in the patient's chart, but told the nurse that he had never noticed it before, since he had had no occasion to look at the chart before the nurse's visit. Shortly thereafter, the patient underwent biopsy and eventual partial mastectomy for breast carcinoma.

Later that year the nurse instituted a malpractice lawsuit against the family physician, the hospital, the mobile imaging company, and the radiologist, claiming that all of the defend-

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ants had violated their duty to her by failing to give her timely notification of the abnormal mammographic results. In subsequent discovery depositions, the family physician stated that although the original 1988 radiology report had obviously been received in the mail by one of his office personnel who inserted it into the nurse's office chart, he himself had had no reason to look at the chart prior to the nurse's visit to him 14 months later because he had never actually ordered the mammogram in the first place, and therefore was not expecting to receive one. The nurse herself stated in her deposition that she never bothered to call the physician about her report, thinking that he would call her if it showed any abnormality. The radiologist said in his deposition that he did not call the doctor because the report was being mailed immediately to him, and had no reason to call the patient because he assumed she would be notified of the results by her physician. He denied any negligent act. Representatives of the hospital and the mobile imaging company said in their depositions that they had adhered to all necessary requirements, as documented by the fact that the radiologist's written report had been received in a timely fashion by personnel in the family doctor's office.

The attorney defending the radiologist asked a nationally prominent expert in mammography for his opinion of whether the defendant had met the ordinary standards of radiologic practice in this matter, and if the answer were affirmative, whether he would serve as the defendant's expert witness. The expert responded that he thought the radiologist was negligent because he failed to telephone the mammographic results to the family physician. The defense attorney contacted another radiologist, however, who in his deposition stated that the defendant radiologist had acted in accordance with the overwhelming majority of radiologists in the nation by arranging to have the report of the abnormal findings mailed, thus fulfilling his legal duty, and that he was not required to telephone the report. On the other side of the dispute, the plaintiff's attorney spoke to still another radiologist experienced in mammography who strongly opined that the defendant was indeed negligent for not having telephoned the family doctor. The attorney also procured copies of American College of Radiology (ACR) guidelines published in 1985 and ACR standards published in subsequent years, which suggested that the radiologist was obliged to telephone the abnormal mammographic results to the patient's physician in addition to mailing them.

Just before the trial adjudicating the case began, all parties agreed to settle the matter for a total payment of \$100,000 to the nurse plaintiff. Sixty percent of this amount was paid by the family physician, 20% by the radiologist, 15% by the hospital, and the remaining 5% by the mobile company. When asked about the settlement afterward, the radiologist's attorney stated that he had deemed it prudent and necessary for the radiologist to pay the \$20,000, because, in his opinion, in the face of the ACR's written standards and guidelines, and the testimony of a radiologist that the defendant had indeed violated those and other published standards, it would have been extremely difficult to convince the jury that the hospital radiologist had not acted in a negligent manner by failing to

telephone the family doctor with the abnormal mammographic results.

Although this settlement sets no legal precedent, it nevertheless does have far-reaching impact on the manner in which radiologists deal with mammography, and on the very nature of the standards of practice against which radiologists are measured.

The Aftermath: The Role of the Radiologist

This case brings into sharp focus what role radiologists play in medical practice today, what their moral and legal duties are, and to whom they owe them. Traditionally, radiologists have considered themselves to be consultants, "doctors' doctors" [1], in the sense that they initiated radiologic examination only on the request of a referring physician and rendered an interpretation for, and transmitted it only to, the same physician. Customarily, the radiographic interpretation has been in the form of a written report. Copies are kept in the radiologist's files, and in hospital records when the examination is performed in a hospital department. Another copy is sent, invariably by first-class mail, to the ordering physician.

Historically it has been believed by the medical community that the radiologist's duty to communicate results stopped with the sending of the radiologic report out of the department, destined to be received by the referring doctor. As a matter of courtesy and good medical practice, the radiologist might decide to telephone the patient's physician if the radiographic findings seemed to warrant immediate treatment, but this was not necessarily required. Little attention was given to the possibility that the report might not be received by the referring physician, or if it were received, that the referring physician would not bother to act on it [2]. The same could be said of any nonradiologic consultant: there has never been an established duty for surgeons, internists, and other medical specialists to telephone or otherwise communicate the results of their consultations to referring physicians beyond sending out written reports.

This seems to be borne out in a study reviewing all of the nearly 1400 malpractice lawsuits filed involving radiologists in the Chicago area during an 11.5-year period [3, 4]. This study revealed that less than 1% of the lawsuits were related to communications disputes, and not a single allegation was lodged against a radiologist that claimed a violation of the duty or responsibility of making sure that the physician who ordered the examination actually received the report. Indeed, I stated in 1990 [5] that I had never seen a case in which a radiologist was held liable for failure of a referring physician to receive a radiologic report, so long as the radiologist issued the report and sent it out in a timely fashion.

The advent of screening mammography changed traditional thinking. Radiologists, who were accustomed to having patients sent to their offices or hospital departments by referring physicians because of specific clinical symptoms or signs, now were being asked to perform mammography on patients who were sent by their doctors simply for screening purposes, and in some cases, on patients who came on their own,

without even being referred by a specific physician. The difference was clear: In the "traditional" referral, the doctor suspected an abnormality, earmarked a specific radiologic examination, and actively awaited the radiologic results; the doctor was apt to follow up with the radiologist if the written report was not received in timely fashion. "No news" was unacceptable: the physician had essentially asked a question of the radiologist and could not close the file on a patient until an answer was received. But in the case of mammography, the mechanics were altered: Both physician and patient often became lulled into the belief that because no clinical signs or symptoms were apparent, a radiologic report indicating an abnormality would be most unlikely, and therefore the result might not be actively awaited. Indeed, no news would tend to become good news: If the radiologist did not react with a report quickly and directly, probably everything was alright.

Perhaps it was because of these perceptions that in 1985 the ACR published and distributed to its members a then little-noticed two-page document, *Policy Statement: Breast Cancer Screening Centers* [6]. In it appear the following statements: "The radiologist must be certain that the result of a positive mammogram is acknowledged by a primary care physician. . . . A positive finding should be reported promptly *in writing* to a physician. . . . In all cases, appropriate acknowledgment of the notification should be sought."

The College's policy covered radiologic facilities that performed mammography on patients who were self-referred or physician referred. It decisively placed a duty on radiologists with which they had never been formally charged before, namely, to seek confirmation that their report was not only sent, but that it had been received. It thus posed the question that is at the heart of the case discussed here: If the radiologist sent the written report but failed to confirm its receipt by the clinician, and if the patient then sustained harm because the physician did not appropriately follow up on the report, would the radiologist be liable, and if so, to whom? To the patient, to the referring physician, or both?

Current Guidelines and Standards

Since 1985, both the ACR and authors in professional journals have had much to say about how and when radiologists should communicate mammographic findings. The *ACR Standards for the Performance of Screening Mammography* [7], published in 1990, state: "All reports in the high probability category should be communicated to the referring physician or his designated representative by telephone, by certified mail, or communicated in such a manner that receipt of the report is assured and documented. . . . Self-referred (i.e., those women who have no referring physician) patients should be notified of the results of the screening study by mail. . . . Reports in the high probability category should be communicated to the patient by certified mail." In its 1991 *ACR Standard for Communication: Diagnostic Radiology* publication [8], the College states: "Some circumstances . . . may require direct communication of unusual, unexpected, or urgent findings to the referring physician in advance of the formal written report. . . . The timeliness of direct communi-

cation should be based upon the immediacy of the clinical situation."

Statements and opinions concerning means of communicating abnormal mammographic findings are seemingly more specific in the radiologic literature. Bird and McLelland [9] in 1986 wrote that if the mammogram is "suggestive of malignancy," the referring physician should receive a "phone report in addition to the written report." Potchen et al. [10] in 1991 wrote regarding mammography that "radiologists should attempt to establish a standard practice of verbal communication whenever a surgical consultation is recommended," and that a notation of the verbal communication be included in the written report. Brenner [11] in 1989 admonished that direct communication between the radiologist and the referring physician is "most likely required" whenever there is the finding of a suspicious lesion on a mammogram, and in a later 1992 article [12] added that a "suspicious mammographic finding imposes upon the radiologist a higher duty for directly communicating the results to the referring physician." On the subject of communicating radiologic results generally, not just limited to mammography, Liston [13] recommended that radiologists should telephone the referring physician before sending a formal report, and Schwinger [14] argued that direct telephone contact should be made because "first class mail is not always reliable" and "the radiologist frequently cannot depend on the clinician reading a written report."

Even the court has had something to say on the subject. A 1987 New Jersey appellate decision stated: "Communication of an unusual finding in an X-ray . . . is as important as the finding itself" [15].

Notwithstanding pronouncements of the ACR and the professional literature, the United States government is less restrictive on the subject of communication. In the 1990 *Federal Register* covering "Conditions for Coverage of Screening Mammography" under the medicare program [16], the only requirement relating to communication of results is that a written report be made and that it be provided to the referring physician or the patient.

Negligence: A Deviation from Standards or a Deviation from Guidelines?

Medical negligence, or malpractice, is legally defined as a breach from standard practice that is the proximate cause of a patient's injury [17]. While we have thus far been discussing what the ACR and medical authorities consider to be guidelines and standards in radiologic practice, specifically as they relate to communication of results, the "standard practice" determined in a court of law may not necessarily be the same. Let us examine more closely what is meant by standard practice. Found in many written state appellate and supreme court decisions dealing with medical malpractice are statements such as "A physician is not required to possess the highest order of qualification, but he must possess and exercise that degree of skill which is ordinarily possessed by members of the profession" [18]; "The law requires a surgeon to possess the skill and learning which is possessed by the average member of the medical profession" [19]; "If a physi-

cian has acted in a manner equal to that ordinarily used by a reasonably well-qualified physician in similar circumstances, the physician is not liable for negligence" [20]; and "Elements of proof of negligence in a medical malpractice case include . . . a deviation or departure from acceptable practice" [21].

What permeates these and other court decisions is the concept that in order for physicians to be found negligent, they must have been shown to have deviated from the usual or ordinary practices, or the standard practices, of the members of their profession, that is, behaved below the average of how their peers would have behaved in similar circumstances. Generally, the court must be instructed as to what constitutes the theoretical "standard" by an expert familiar with the profession in question. The expert explains to the judge and/or jury what the average or ordinary physician would have done under a comparable circumstance, and then offers an opinion as to whether the physician defendant acted within or below that standard [22].

Real standards of practice do not derive from any external authority such as government or professional societies, but rather come from interaction among leaders of a profession, journals, meetings, networks of colleagues, flow of reports in the literature, and peer discussions; it is a decentralized process of policy setting [23]. It is a valid question, then, to ask ourselves whether a guideline, standard, or parameter published by a professional society or the American Medical Association, or an opinion stated by an authority in a journal, which purports to tell members of a professional group how they *should* act, adequately and accurately reflects how the average member of the group indeed *does* act. Do these published standards portray to the community at large how radiologists realistically do things in today's world? Do they give the court an accurate indication of a level of average and ordinary practice, below which any conduct would be considered negligent? The express purpose of the standards now being formulated and released by the ACR is to improve quality of care, which is in keeping with the College's mission, namely, to "improve radiologic service to the patient" [24]. But whether the College's standards set new standards, or simply reflect existing ones, is certainly not very clear. A disclaimer placed on every page of the ACR standards states that: "The standards . . . are not rules but attempts to define principles of practice. . . . The standards should not be deemed inclusive of all proper methods of care." While this sounds like the ACR is not mandating a standard of practice on its radiologist members, the disclaimer then goes on to read: "It is prudent to document the rationale for any deviation from these suggested standards."

A debate about whether the legal standard is what we actually do or what we should do is largely academic. While the courts will theoretically continue to judge defendant radiologists on the basis of whether they did the same or less than what their peers would have done under similar circumstances, rather than on how the ACR or American Medical Association guidelines would have dictated they should have acted, we must be mindful that just as the published standards influence practicing radiologists, so will they greatly influence the courts. Indeed, the ACR's legal counsel has

stated that the plaintiff's attorney will clearly use those standards as a "weapon" to try to indicate that the defendant radiologist was negligent, and reference to them in court proceedings may well occur with greater frequency in the future. One of the lessons of this case may be that it behooves all radiologists to acknowledge that even if certain of their practice patterns do not conform to the published standards today, they will have to be modified to comply with the standards eventually, not only to improve the quality of service, but also to minimize legal vulnerability.

How High Is the Standard

The attorney defending the radiologist in this case recommended that his client pay one fifth of the total liability, because the radiologist did not telephone the abnormal results of a mammogram to the physician listed on the mammogram requisition form, even though he knew the written report would be properly and promptly mailed to that physician. Several leading radiology experts say the defendant *should* have telephoned the referring doctor, published standards and guidelines say he *should* have telephoned the doctor, and possibly the preponderance of opinion in today's climate in the radiologic community is that he *should* have telephoned the referring physician. But one must wonder whether most practicing radiologists *would* actually have telephoned the doctor in 1988 under similar circumstances, and, more fundamentally, whether by not telephoning the doctor, the radiologist was truly guilty of malpractice. Although there is no formal judicial finding in this case, it is reasonable to conclude that the defense attorney was quite correct in his prediction that the radiologist would have been found to have deviated from professional standards, and thus to have been negligent. It is also reasonable to conclude that had the radiologist indeed telephoned the family physician with the positive mammographic findings, no malpractice, and probably no lawsuit, would have occurred in the first place.

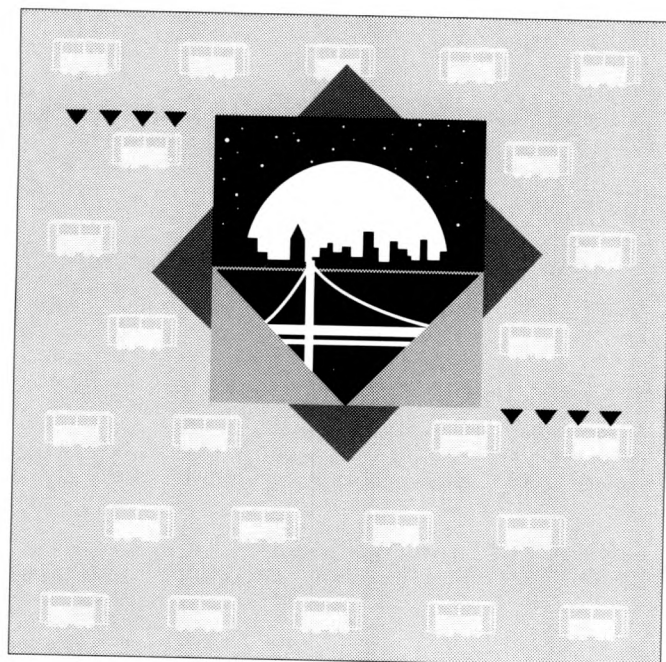
Under our legal system, radiologists are guilty of malpractice if it is proved that they have conducted themselves below the standard of their profession. The standard is what our professional organizations, which are composed of our peers and appointed or elected leaders, say it is. The standard, of necessity, becomes more complex and continuously is elevated to greater heights, parallel to our geometric increase in medical knowledge, our explosive growth in sophisticated electronics and technology, and our relentless effort to constantly improve service to our patients and referring physicians.

At what level is the standard today and how much further can our colleagues and the courts take it? As deep as the ocean, as high as the sky?

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Letters

Luetic Aneurysm of the Innominate Artery Mimicking a Mass in the Right Side of the Anterior Mediastinum: MR Appearance

Luetic aneurysms of the innominate artery are uncommon and on chest radiographs may mimic a mass in the right side of the anterior mediastinum. We describe the MR features of such a case.

A 66-year-old man was admitted because of progressive dyspnea. He had a long-standing history of hypertension and emphysema and had been treated for syphilis 20 years before this admission. Posteroanterior and lateral chest radiographs showed a 2-cm masslike opacity with well-defined borders in the right side of the anterior mediastinum (Fig. 1A). CT with IV contrast material showed a partly enhancing mass at the anterior site of the ascending aorta. On the basis of this study and the patient's history of syphilis, aneurysm of the ascending aorta was considered as a possible diagnosis. We postulated that the nonenhanced part of the aneurysm represented a thrombus within the aneurysm. On angiograms of the aortic root, the aneurysm appeared to be localized at the base of the innominate artery. Because the patient had chronic respiratory insufficiency, surgery was not considered.

Three months later, MR imaging was performed to study the MR features of the aneurysm and to determine if the size of the abnormality was increasing. A Philips T5 imager (0.5 T), cardiac gating, and a multislice spin-echo sequence with a TE of 15 msec and an effective TR of 461 msec were used. Oblique images showed an aneurysm 2 cm in diameter at the right side of the origin of the innominate artery (Fig. 1B). No flow void was present in the aneurysm, suggesting the presence of thrombus.

Aneurysms of the innominate artery are rare and account for 3% of all aneurysms [1]. Syphilis is the most common etiologic factor [1]. The diagnosis was not initially considered after CT because it was difficult to differentiate an aneurysm localized in the ascending aorta from an aneurysm of the innominate artery. Buckling and tortuosity of the innominate artery are more frequent entities and often occur in hypertensive females. These entities may also simulate a right-sided mass in the upper mediastinum [2, 3]. Unlike aneurysms, which may rupture, resulting in death, buckling of the innominate artery is a benign condition [3]. Because of difficulties in differentiating an aneurysm from buckling of the innominate artery on axial CT scans, we think that CT plays a minor role in the imaging of these aneurysms. When the aneurysm is completely filled with thrombus, the diagnosis may be missed even with CT [4].

MR imaging is noninvasive and can show the longitudinal course of the innominate artery. Consequently, it seems to be the technique

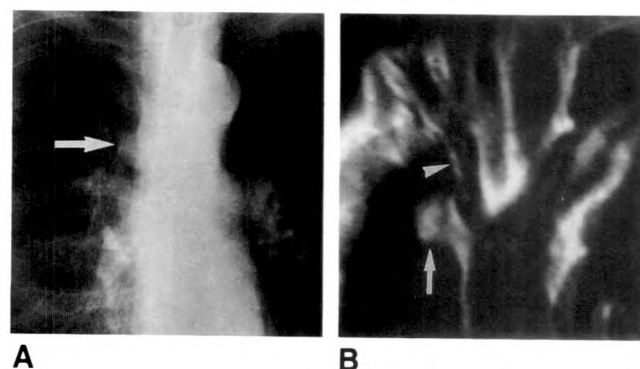


Fig. 1.—Luetic aneurysm of innominate artery mimicking a mediastinal mass.

A, Radiograph shows lesion (arrow) in right side of mediastinum that appeared to be localized in anterior mediastinum on lateral radiograph (not shown).

B, Oblique cardiac-gated T1-weighted spin-echo MR image shows aneurysm (arrow) at origin of innominate artery (arrowhead). Note absence of flow void in aneurysm, indicating formation of thrombus.

of choice for imaging aneurysm or buckling of this vessel. Angiography should be limited to those cases in which the MR findings are equivocal and further differentiation of an aneurysm from buckling of the innominate artery is needed.

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A New Technique for Retrieving Catheter Fragments in the Pulmonary Artery

A new loop-snare system for retrieving catheter fragments in the pulmonary artery has been devised (Fig. 1). The system is composed of a 5-French Berman angiographic balloon catheter and a 0.018-in. (0.46 mm) guidewire 260 cm long (Hanako Medical, Chiyoda, Japan). The catheter originally had two sets of three small side holes at the tip; the walls between the distal two holes of one set and the proximal two holes of another set were removed, yielding two large holes, one for each set of side holes. A loop snare was formed, with the long guidewire inserting through the two large holes. This system, the balloon catheter with the wire loop, can be safely and easily advanced into the pulmonary artery.

The newly devised loop-snare method was used in a 6-year-old girl who had a catheter fragment in the left pulmonary artery. She had previously had an IV catheter fragment in the inferior vena cava. An attempt had been made to retrieve it by using an 8-French Dotter Intravascular Retriever Set (Cook, Bloomington, IN). The fragment was accidentally cut in two. One of the two pieces was carried away into the pulmonary artery. The newly devised loop snare was advanced into the left pulmonary artery with the balloon inflated, and the tip of the catheter was placed in the artery smoothly and safely. We retrieved the fragment in 1 min (Fig. 2).

Many nonsurgical techniques for the retrieval of catheter fragments in the pulmonary artery have been reported [1-3]. They can be classified into three groups according to the instruments used: loop snare, grasping forceps, and basket retriever. Our new retrieval system is a loop-snare system, but it has some advantages over the

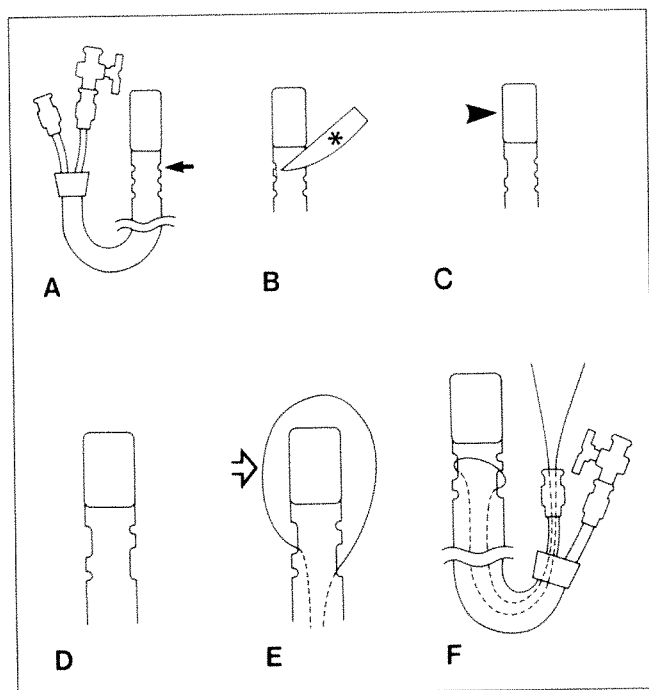


Fig. 1.—Schematic drawing of procedure for making modified loop-snare device from Berman angiographic balloon catheter and long thin guidewire.

A, Angiographic balloon catheter. Arrow indicates side hole.

B-D, Walls are removed between distal two small side holes on one side and between proximal two on other side, yielding two large side holes, one on each side of catheter. Asterisk = knife, arrowhead = balloon.

E and F, Loop snare is formed by inserting long guidewire (open arrow) through two large side holes.

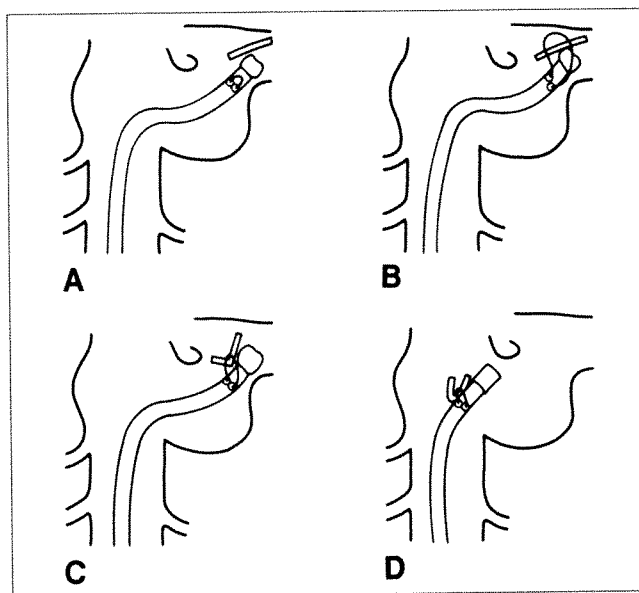


Fig. 2.—A-D, Schematic drawing shows procedure for using loop-snare retrieval system to remove catheter fragment from left pulmonary artery.

conventional techniques. Our system is safer, easier, and more reliable than stiff-tipped catheters from the point of view of handling. Because of the balloon at the tip of the catheter, even an inexperienced operator can advance the tip with the snare loop into the left pulmonary artery with little difficulty. The snare loop is easier to open than the usual ones because the modified side holes are large enough to accommodate the wire. Furthermore, this system can be made easily from catheters available in any cardiovascular laboratory and is not expensive.

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Percutaneous Ethanol Injection in Bleeding Hepatocellular Carcinoma

Recently, Chung et al. [1] reported findings in three patients with bleeding hepatocellular carcinoma who were successfully treated by intratumoral injection of alcohol during laparotomy. We describe the first case of control of bleeding hepatocellular carcinoma by sonographically guided percutaneous injection of alcohol.

Fig. 1.—Sonogram shows peritoneal fluid collection (arrowhead) and hyperechogenic tumor nodule (arrow) injected with absolute alcohol in woman with bleeding hepatocellular carcinoma.



A 60-year-old woman with alcoholic cirrhosis was hospitalized because of sudden abdominal pain and anemia. She had diffuse abdominal tenderness. Blood pressure and pulse rate were normal. Relevant laboratory results were as follows: hemoglobin, 6.8 g/dl (68 g/l); hematocrit, 14.2% (0.14); prothrombin time, 52% of control; total serum bilirubin, 52 μ mol/l; serum alkaline phosphatase, 267 IU/l (normal, <170 IU/l) and α -fetoprotein, 146 ng/ml (146 μ g/l; normal, <6 μ g/l). Endoscopy showed nonbleeding esophageal varices. Sonography showed large perihepatic and intraperitoneal fluid collections; a 6-cm superficial tumor in the right lobe of the liver, with a contiguous 2-cm intraparenchymal nodule; and thrombosis of the portal vein. Abdominal paracentesis was used to remove bloody ascitic fluid. The most likely diagnosis was ruptured hepatocellular carcinoma, and as emergency treatment, 20 ml of absolute alcohol was injected percutaneously, under sonographic guidance, into the largest tumor (Fig. 1). The tumor was injected with 20 ml of alcohol three more times during the ensuing 2 weeks. The final diagnosis of hepatocellular carcinoma was established on the basis of the results of percutaneous biopsy of the smallest lesion. An additional 20 ml of alcohol was injected at the time of biopsy. Three weeks later, hemoglobin was 120 g/l, serum α -fetoprotein was 44 μ g/l, and the ascitic fluid was yellow clear. Four months later, the patient was well. The two hepatic lesions were 4.5 cm and 1.5 cm in diameter, respectively, at that time.

Percutaneous injection of ethanol has recently been proposed for treatment of uncomplicated hepatocellular carcinoma [2]. Our results suggest that this easy and safe procedure can also be used successfully in the treatment of ruptured hepatocellular carcinoma complicated by intraperitoneal hemorrhage. Findings on sonography enabled us in an emergency to both diagnose and treat this rare, but often fatal, complication. Thus, in patients with cirrhosis and poor cellular function, the high mortality associated with emergency hepatectomy or ligation of the hepatic artery can be avoided [3]. In countries where this complication is common, a prospective evaluation of less aggressive methods such as percutaneous injection of alcohol or angiographic embolization must be undertaken.

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Atypical Choledochal Cyst

In his review article on pediatric biliary sonography [1], Haller proposes a scheme devised by Alonso-Lej et al. [2] for classifying choledochal cysts into three major types: type 1, concentric dilatation of the common bile duct; type 2, diverticular outpouching of the common bile duct; and type 3, choledochoceles. In a previous article in the *AJR*, Savader et al. [3] proposed a scheme outlined by Todani et al. (cited in [4]) that classifies choledochal cysts into five types and subtypes as follows: type 1A, cystic dilatation of the common bile duct; type 1B, focal, segmental, dilatation of the common bile duct; type 1C, fusiform choledochal dilatation; type 2, true choledochal diverticulum; type 3, choledochoceles; type 4A, multiple intrahepatic and extrahepatic cysts; type 4B, multiple extrahepatic cysts; type 5, Caroli's disease. We recently treated a patient who had an unusual choledochal cyst that does not conform to any of these types.

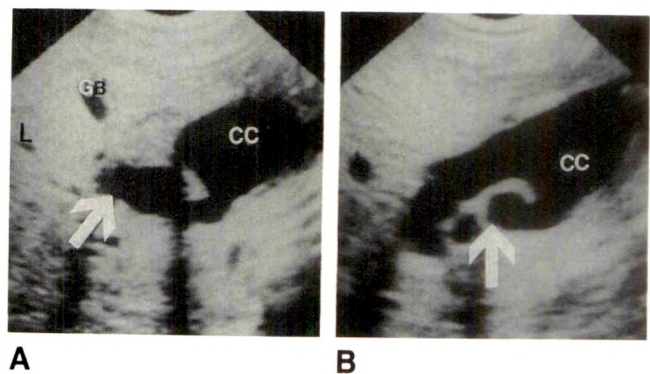


Fig. 1.—A and B, Coronal (A) and oblique (B) abdominal sonograms show choledochal cyst (CC) as a fusiform dilatation of terminal part of common bile duct. Note associated diverticulum arising from right lateral wall of duct (arrow). L = liver, GB = gall bladder.

A 4-year-old girl had clinical findings suggestive of recurrent cholangitis. Abdominal sonography showed fusiform dilatation of the common bile duct, which was 2.3 cm in diameter. In addition, a small diverticulum arose from the right lateral wall of the dilated duct (Fig. 1). The atypical nature of the choledochal cyst was confirmed at cholangiography and at surgery. The cyst in our case was unusual and did not conform to any of the previously described types. At best it was a combination of types 1 and 2 according to the scheme proposed by Alonso-Lej et al. and types 1C and 2 according to the classification of Todani et al. Fortunately, such choledochal cysts are exceptional and do not justify a modification of the proposed classifications.

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Fat-Containing Collection Adjacent to Intrahepatic Inferior Vena Cava: Sonographic Detection and Characterization

Miyake et al. [1] recently described the CT and MR features of a localized fat collection adjacent to the intrahepatic portion of the inferior vena cava, a normal variant found in 0.5% of patients. We have had one case of a similar entity, which was discovered initially on sonograms. Our observations should help establish the imaging features.

A 38-year-old woman had lost weight (a few kilograms) over a period of several months and had had intermittent pain in the right upper quadrant for 2 weeks. She had no other signs or symptoms, and the results of blood tests were normal, including liver function tests. Sonography elsewhere had shown a $3.2 \times 2.5 \times 2.0$ cm slightly hypoechoic entity anterior to the inferior vena cava; it was thought to be malignant. Sonography at our institution showed that the entity was anteromedial to the inferior vena cava (Fig. 1A), both at and just above the confluence of the hepatic veins and the inferior vena cava. The veins did not appear to be compromised, and the entity was slightly hypoechoic relative to liver. Some sonograms showed a hyperechoic thin fascia coursing through the entity and dividing it into two components: one smaller and anterior and one larger and posterior. Our impression was that the entity was benign and probably an anatomic variant. CT showed a hypodense structure with an almost rectangular configuration on axial scans (Fig. 1B). This was so despite the oval configuration on sonograms. Attenuation values before and after administration of contrast material were as follows: focal entity, 30 H and 60 H, respectively; liver parenchyma, 60 H and 100 H, respectively. On 30-min delayed scans, the attenuation values were 50 H for both the focal structure and the inferior vena cava and 75 H for the liver parenchyma. We recommended follow-up with sonography. The patient's pain disappeared entirely within days, and the sonographic findings had not changed up to 10 months later.

The entity described by Miyake et al. broadens the spectrum of normal variants seen on CT and MR imaging of the liver. Our case appears to be another example of the variant they described. They found attenuation values of -113 H to -23 H before administration of contrast material, which suggest these entities can contain a broad range of mixtures of fatty and other connective tissues. The findings in our case suggest an even broader range, as the attenuation values were positive, rather than negative.

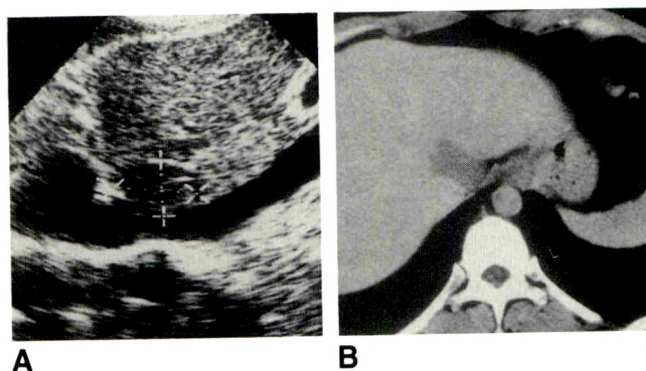


Fig. 1.—Fat-containing collection adjacent to intrahepatic inferior vena cava (IVC).

A, Sonogram shows slightly hypoechoic structure anteromedial to IVC.
B, Contrast-enhanced CT scan shows a hypodense entity immediately anteromedial to IVC, which is isodense with liver.

Localized foci hypoechoic relative to liver have been documented as normal variants in several areas. Berland [2] described those in the area of the porta hepatis, which were demonstrable on sonograms but not at all detectable on CT scans. These variants are ovoid to irregular; the longest axis recorded was 4 cm (mean, 2.7 cm). The entire posterior part of the lateral segment of the left lobe of the liver may have low echogenicity and a lobular appearance, which is the result of reverberation artifact [3]. The entity detected in our patient was also slightly hypoechoic relative to liver. In the study by Miyake et al., the maximum dimension of the variant they described was 22 mm on CT scans. In our case, the maximum dimension on sonograms was 32 mm.

The exact imaging characteristics of a fat-containing collection will likely include subtle variations, depending on factors such as the proportion of fat to other connective tissue stroma. In normal variants, such as the one we have described, histologic confirmation is unlikely and undesirable. Possibly, future imaging of such fat-containing collections will further clarify the range of imaging characteristics, especially if MR signal intensity ratios in relation to liver and subcutaneous fat are determined.

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Duplicated Gall Bladder and Situs Inversus: Findings on Sonography and Scintigraphy

Meistrup et al. [1] recently described and illustrated a wide variety of gallbladder anomalies. They mention the left-sided location in situs inversus totalis, as expected. However, they merely state that duplicated gallbladders are challenging and difficult to detect on sonography, oral cholecystography, and scintigraphy. Indeed, no example of a duplicated gallbladder is included in their pictorial essay, which is not surprising, as the estimated prevalence of this anomaly is one in 5000 [2].

We illustrate a case of a duplicated gallbladder in a patient with situs inversus. Sonograms clearly showed two totally distinct gallbladders, each with its own cystic duct (Figs. 1A-1C). Scintigrams showed a double gallbladder contour (Fig. 1D). The biliary findings were unrelated to the patient's mild hepatic and renal dysfunction, which were the result of prostatic carcinoma with metastatic features.

Duplication of the gallbladder can be mimicked by a folded gallbladder, choledochal cyst, phrygian cap, pericholecystic fluid, gallbladder diverticulum, vascular band across the gallbladder, focal adenomyomatosis, and even an intraperitoneal fibrous band sequestering a portion of the gallbladder [3]. Our case shows that complete duplication of the gallbladder can be clearly established by careful sonography and that the finding of a double gallbladder contour on scintigrams should also suggest the possibility of a duplicated gallbladder. Duplications in which the cystic ducts cannot be well delineated, such as when one cystic duct enters directly into the liver [4],

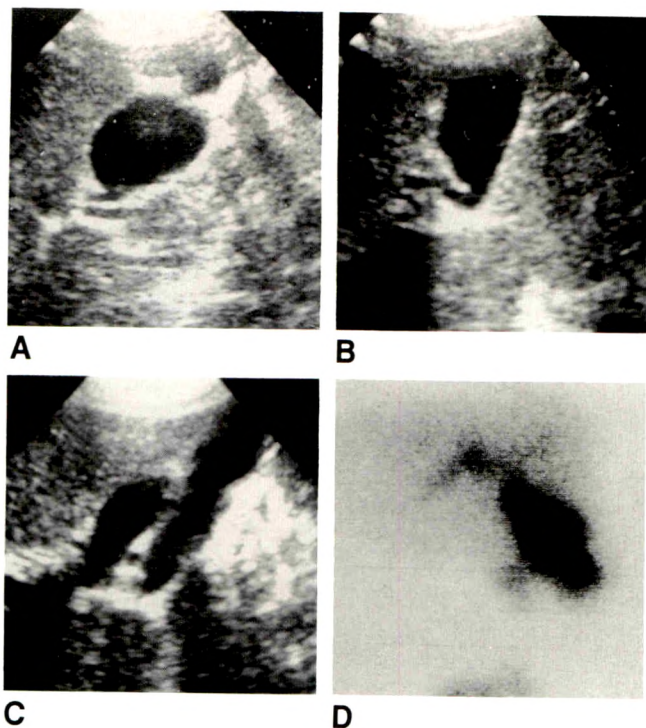


Fig. 1.—Duplicated gallbladder in a patient with situs inversus. **A and B,** Sonograms show two gallbladders, (one in **A** and one in **B**) with distinctly different configurations. Note cystic duct on each gallbladder. **C,** Oblique sonogram shows two adjacent gallbladder lumens. **D,** Scintigram shows situs inversus and double contour of gallbladder.

will be more difficult to assess with sonography alone. An anomalously positioned second gallbladder will also be more difficult to detect.

Corcoran et al. [4] suggested that duplicated gallbladders are more prone to inflammation and stone formation, so detection of a duplicated gallbladder is always clinically important. A detailed review [5] of 148 cases of anomalies of the gallbladder included 28 cases of duplicated gallbladder but no cases of situs inversus. Although almost any gallbladder anomaly might be expected to occur more often in a patient with situs inversus, our case appears to be the first one of a duplicated gallbladder in such a patient.

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Hydatid Cyst of Spleen with Bull's-eye Appearance on Imaging

We read with interest the pictorial essay, "MR Imaging in Hydatid Disease," by von Sinner et al. [1]. We recently treated a patient who had a giant, isolated splenic hydatid cyst with an unusual "bull's-eye" appearance.

A 32-year-old woman had a painless and progressively enlarging mass in the left upper quadrant. Real-time sonography with a 3.5-MHz sector transducer (Sonoline AC, Siemens) showed the mass was a well-defined cystic lesion difficult to distinguish from spleen. The cyst contained well-defined linear echodensities that, on closer scrutiny, were multiple membranous laminations, giving a characteristic bull's-eye appearance. MR imaging (Hitachi MRP-20 scanner at 0.2 T) showed a large fluid-filled mass that was hypointense on T1-weighted images and hyperintense on T2-weighted images. Within this mass, multiple isointense membranes curled on themselves, producing the bull's-eye appearance (Fig. 1). Surgery confirmed the presence of a giant, isolated splenic hydatid cyst. Pathologic examination of the surgical specimen showed that laminated infoldings of the germinal epithelium were the cause of the bull's-eye appearance.

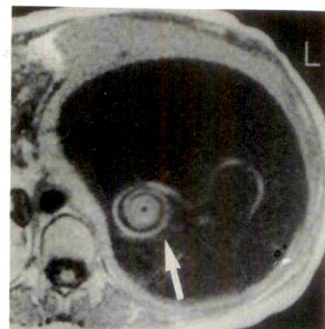


Fig. 1.—T1-weighted MR image shows giant splenic hydatid cyst with folded germinal epithelium producing a "bull's-eye" appearance (arrow).

The activity of the germinal epithelium in a hydatid cyst produces a variety of distinctive appearances on cross-sectional images [2]. The presence of a fluid debris level (caused by hydatid sand), daughter cysts, and the water-lily sign, which indicates complete collapse of the hydatid cyst, are virtually pathognomonic of this entity. A bull's-eye within a splenic hydatid cyst, the result of multiple infoldings of the germinal epithelium, is another uncommon, but distinctive appearance of this fascinating entity.

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Polyp Arising in a Colonic Diverticulum

Colonic diverticula and polyps commonly coexist, and accurate differentiation of these two entities on air contrast barium enema is crucial. Several authors [1, 2] have addressed this question, and reported cases include colonic diverticula with inspissated stool simulating a polyp [3]. We report an unusual case of a polyp arising at the orifice of a colonic diverticulum that appeared to be a diverticular filling defect on air contrast barium enema.

A 69-year-old woman had heme-positive stools. Air contrast barium enema showed cecal diverticula. One of the diverticula contained a single, round filling defect (Fig. 1A). Subsequent colonoscopy showed a 20-mm polyp arising at the orifice of one of the diverticula (Fig. 1B). The short, broad-based stalk of the polyp straddled the diverticular orifice, with the head of the polyp lying within the diverticulum. Colonoscopic polypectomy was performed, and pathologic examination showed the lesion was a tubulovillous adenoma.

Distinguishing between colonic diverticula and polypoid lesions on air contrast barium enema can be difficult, and various methods of differentiation have been described. These include use of the "bowler-hat sign" [2] and the "border sign" [4] and evaluation of the sharpness of the inner or outer ring of the diverticulum or polyp. In our case, cecal diverticula were present according to the aforementioned criteria. However, the filling defect within one of the diverticula was the puzzling aspect of this case. Possible causes of this finding include a polyp, inspissated stool, partial inverting diverticulum [5], and extrinsic compression. Although filling defects within diverticula are often attributed to inspissated stool, the potential presence of a polyp within a diverticulum warrants further investigation. In our case, subsequent colonoscopy confirmed the presence of a polyp lying within a cecal diverticulum.

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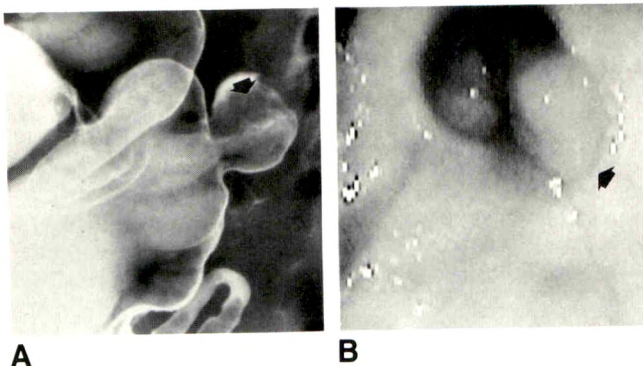


Fig. 1.—Polyp in a colonic diverticulum.
A, Air contrast barium enema shows filling defect (arrow) straddling orifice of diverticulum.
B, Photograph obtained at colonoscopy shows polyp (arrow) at mouth of diverticulum. Head of polyp lies inside diverticulum.

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Congestive Heart Failure in a Patient with Autosomal Dominant Polycystic Kidney Disease

The following report concerns the association between cardiovascular anomalies and autosomal dominant polycystic kidney disease (ADPKD).

A 45-year-old man with a family history of kidney disease arrived at the emergency department with new-onset congestive heart failure and a heart murmur. A real-time sonogram of the abdomen showed multiple simple cysts in the kidneys, liver, and spleen, consistent with the diagnosis of ADPKD. A transthoracic echocardiogram showed a bicuspid aortic valve and moderate calcific aortic stenosis (Fig. 1A). A coronary angiogram showed dilatation of the aortic root and severe aortic insufficiency (Fig. 1B). The patient had uneventful aortic valve replacement. Examination of the resected aortic valve showed extensive hyalinization and myxomatous degeneration.

ADPKD is the most common genetic disease and accounts for about 10% of patients with end-stage renal failure [1]. The reported prevalence of cardiovascular abnormalities in patients with ADPKD is variable, between 18 and 31% [2, 3]. Aortic insufficiency and dilatation of the aortic root are the most common findings on angiograms and at surgery [2]. Mitral valve incompetence and mitral valve prolapse are the most common on echocardiograms [3]. Many patients also have congenital bicuspid aortic valve and calcific aortic stenosis [2].

Myxomatous degeneration is a nonspecific term for disorganization and loss of collagen. It is speculated that in ADPKD, this change is the result of a collagen defect similar to those seen in Marfan's and Ehlers-Danlos syndromes [2, 3]. In these conditions, basic defects exist in the quantity or quality of collagen. The aortic and valvular defects in ADPKD may simply be part of a spectrum of abnormalities, including visceral cysts and intracranial aneurysms, caused by a genetically determined variation in the extracellular matrix.

Radiologists need to be aware of associated cardiovascular anomalies when they examine patients with polycystic kidneys and are in a position to inform primary care physicians of the possible coexist-

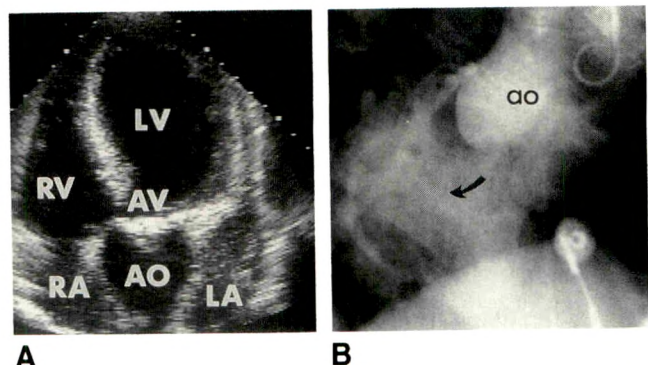


Fig. 1.—Cardiovascular abnormalities in a patient with autosomal dominant polycystic kidney disease.

A, Transthoracic echocardiogram shows a moderately calcified aortic valve (AV). LV = left ventricle, RV = right ventricle, RA = right atrium, AO = aortic root, LA = left atrium.

B, Cine frame from cardiac catheterization shows a dilated root (ao) and aortic insufficiency (arrow).

ence of these two conditions. Currently, the usefulness of screening patients with ADPKD for possible cardiovascular abnormalities has not been established. Moreover, the technique for screening remains to be established. Echocardiography and MR imaging may provide the greatest amount of diagnostic information with the least risk to ADPKD patients, who are known to have decreased renal function and may be at risk for acute tubular necrosis associated with use of contrast material [4].

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Late Total Closure and Caudal Migration of an LGM Caval Filter

Placement of intraluminal caval filters is a safe method of vena caval interruption. In the past 20 years, the Greenfield filter was the most commonly used device. However, new devices that can be placed percutaneously are now available. We report an unusual complication of an LGM filter: late closure of the device associated with caudal migration and vena caval thrombosis.

An 86-year-old woman with a history of recurrent thrombophlebitis was admitted for treatment of massive pulmonary embolism. Interruption of the inferior vena cava was the procedure of choice because of the high probability of recurrent pulmonary embolism despite adequate heparin therapy. An inferior vena cavogram was normal. An LGM filter (L. G. Medical, Monts-sur-Guesnes, France) was placed percutaneously without incident via the right femoral vein. An abdominal radiograph confirmed adequate opening and placement of the filter (Fig. 1A). The patient was discharged a few days later. Oral anticoagulant therapy was stopped 4 months later, and the subsequent course was uneventful during the next 2 years. At that time, the patient was readmitted because of evidence of abdominal collateral circulation without leg edema or signs or symptoms of pulmonary embolism. Abdominal radiographs showed slight downward migration and total closure of the filter. Subsequent retrograde cavography showed complete thrombosis of the inferior vena cava at the filter site. The side rails of the filter were compressed by the thrombus (Fig. 1B). Perfusion lung scan showed no new perfusion defect, and anticoagulative therapy was reinstituted. However, no clinical improvement was observed 1 year later, and abdominal radiographs showed that the device remained closed.

Incomplete opening of LGM filters at the time of insertion has been described [1] and may be a cause of recurrent pulmonary embolism. However, in our patient, this hypothesis was excluded because abdominal radiographs obtained immediately after placement showed that the filter was open. Closure occurred late after insertion and likely was related to the development of caval thrombosis. As suggested by Geisinger et al. [2] for the Greenfield filter, retraction of the thrombus embedded within the device might also retract the side

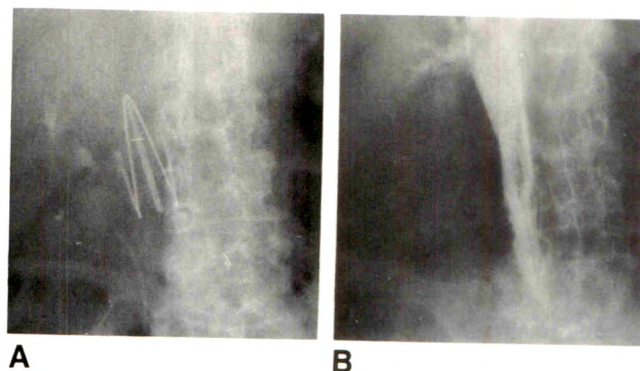


Fig. 1.—A, Abdominal radiograph obtained immediately after placement of LGM filter in inferior vena cava shows filter is open and in satisfactory position.

B, Inferior vena cavogram obtained 2 years 4 months after A shows thrombus embedded within filter, slight downward migration of filter, and a decrease in filter's span.

rails of the LGM filter and close it. Although as yet seldom reported [3, 4], the prevalence of this complication will probably increase, as currently most percutaneously placed filters do not penetrate the wall of the inferior vena cava as the Greenfield device does. We therefore suggest that an abdominal radiograph should be obtained as part of the routine follow-up examination of patients after percutaneous placement of a vena caval filter.

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Dermoid Mesh: A Sonographic Sign of Ovarian Teratoma

With contemporary imaging techniques, the appearance of most ovarian neoplasms is nonspecific. Cystic ovarian teratoma, however, is an exception. The presence of a dermoid plug, a fat-fluid level, or a tooth is pathognomonic for this entity. We describe another sonographic appearance, the "dermoid mesh," which we have found is a fairly accurate marker of cystic ovarian teratomas.

The term dermoid mesh stems from our experience with seven cases of cystic ovarian teratomas diagnosed on the basis of pelvic sonography with a 3.5-MHz transducer (Sonoline AC, Siemens). The dermoid mesh, a tangle of entwined linear interfaces floating within the cyst, unattached to the wall of the cyst, was present in all seven cases. The dermoid mesh was also clearly seen in the three of these seven patients who had transvaginal sonography (Fig. 1). Examina-

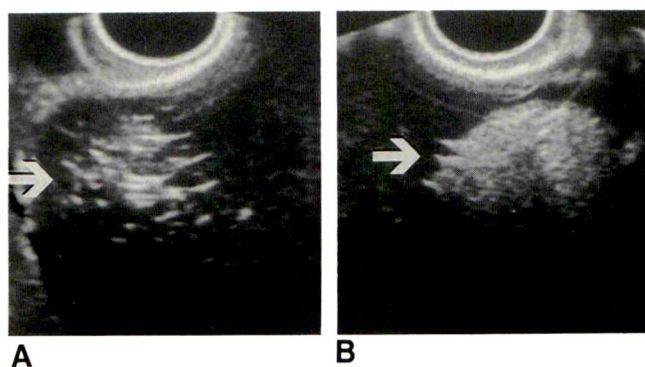


Fig. 1.—A and B, Transvaginal sonograms show “dermoid mesh” (A, arrow) and, at a different level, dermoid plug (B, arrow) within cystic ovarian teratoma.

tion of surgical specimens in all seven cases confirmed that the dermoid mesh resulted from the reflecting interfaces produced by a tangle of hair floating within the cyst. In addition to the dermoid mesh in five of the seven cases, other findings were as follows: curvilinear, mural calcification (one patient); tooth (two patients); and dermoid plug (four patients). In two patients, the dermoid mesh was the only sonographic finding that provided a clue to the true nature of the ovarian cyst.

The entwined nature of the linear echoes in a dermoid mesh, which are separate from the cyst wall, can be used to distinguish it from the septa seen in a variety of ovarian neoplasms or with floating particulate matter in hemorrhagic ovarian cysts. Although in the past, the emphasis has been on the detection of fat, bone, or tooth in a cystic ovarian teratoma, the importance of the dermoid mesh is underscored by the findings of Caruso et al. [1]. In an intense, retrospective clinicopathologic study of 305 teratomas of the ovary, they found that the prevalence of skin (99.3%) and skin appendages (96.8%) far outnumbered the prevalence of fat (67.4%), bone (18.6%), and tooth (7.7%).

Although we have made no attempt to assess the relative merits of sonography, CT, and MR imaging in the detection of the dermoid mesh, we think that the internal characteristics of the mesh would be shown best by sonography.

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Stress Fracture Detected Sonographically

In cases of stress fractures, plain radiographs may be normal for several weeks before callus or a fracture line becomes apparent [1]. We present a case of foot pain due to a stress fracture of the second metatarsal in which plain radiographs were normal and sonograms showed the injury.

A 50-year-old woman had had pain and swelling over the dorsum of the right foot for 12 days. As part of a recently started weight-reducing regimen, she had been walking 5 km/day 6 days a week

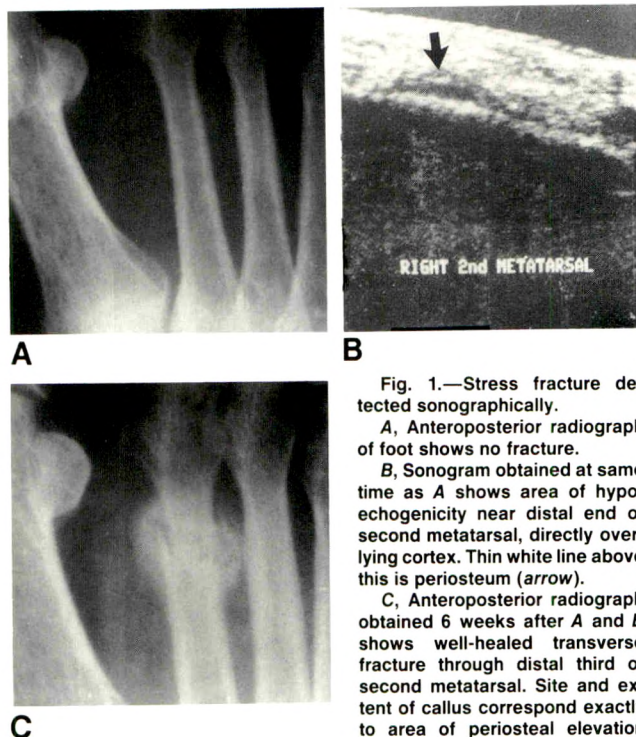


Fig. 1.—Stress fracture detected sonographically.

A, Anteroposterior radiograph of foot shows no fracture.

B, Sonogram obtained at same time as A shows area of hypoechogenicity near distal end of second metatarsal, directly overlying cortex. Thin white line above this is periosteum (arrow).

C, Anteroposterior radiograph obtained 6 weeks after A and B shows well-healed transverse fracture through distal third of second metatarsal. Site and extent of callus correspond exactly to area of periosteal elevation seen on B.

before the onset of pain. On examination, she walked with a limp, bearing weight on her heel. She had some soft-tissue swelling on the dorsum of the foot and marked tenderness in the area of the second and third metatarsals. Complete blood cell count and erythrocyte sedimentation rate were normal, as were the plain radiographs (Fig. 1A). Sonograms of the foot were obtained from the dorsal aspect with a Sonoline SL1 system and a 7.5-MHz linear transducer. A small localized area of periosteal elevation was seen over the second metatarsal, which corresponded to the tender area (Fig. 1B). A diagnosis of stress fracture was made on the basis of this examination, and the foot was put in a plaster cast for 3 weeks. A follow-up radiograph obtained 6 weeks later confirmed the presence of a healed stress fracture (Fig. 1C).

Stress fractures are produced by repeated cyclic loading of the bone; the load is much less than that required to produce an acute fracture. On plain radiographs, a stress fracture may not be visualized for up to 10 weeks after the time the injury occurred [1]. Technetium bone scanning has been used, and increased uptake of radionuclide in the late phase is indicative of stress fracture, although the false-positive rate is high with this technique [2]. The periosteum, particularly when elevated off the bone, is well visualized on sonograms [3]. Sonography is not normally considered a good technique for imaging bone, but, paradoxically, it was superior to plain radiography in the diagnosis of this fracture.

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Subungual Glomus Tumor: Diagnosis Based on High-Resolution MR Images

A 31-year-old woman had had aching pain and acute point tenderness beneath the nail of the fifth digit of the left hand for 4 months. The pain was worse at night and was relieved by aspirin. Temperature changes induced severe paroxysmal attacks of pain. No longitudinal ridging or other change in the nail plate was present, and the lesion was not visible on physical examination. A radiograph showed a slight bony condensation with a small trabeculated convexity of the dorsal ungual phalanx diaphysis, but no abnormality of the adjacent soft tissue. This was considered suggestive of osteoid osteoma. Findings on CT scans were normal. MR images were obtained with a whole-body system operating at 1.5 T (Signa, GE Medical Systems, Milwaukee, WI). In routine use, spatial resolution is only 0.3 mm, which is insufficient for accurate visualization of small lesions within the dermis. A specific high-resolution imaging module consisting of a surface gradient coil and a small surface RF coil was therefore used. The same imaging module has been used to obtain high-resolution MR images of the wrist, the finger, and the skin [1, 2].

Axial and sagittal spin-echo interleaved multislice sequences were obtained. The field of view of the axial images was 20×20 mm, corresponding to a pixel size of $78 \times 156 \mu\text{m}$. High-resolution MR images showed a well-defined, oval soft-tissue lesion that was 2 mm along the transverse axis and 3 mm along the longitudinal axis. The mass was dorsal to the ungual phalanx diaphysis, in the dermis, beneath the proximal nail, which appeared on sagittal images as a straight hypointense line. The nodule was homogeneous; it had a moderately intense signal relative to that of the normal surrounding soft tissue on T1-weighted and proton density-weighted images and a high-intensity signal on T2-weighted images (Fig. 1A). Gradient-

echo images showed a mass that was hyperintense compared with normal adjacent soft tissue. Axial images showed smooth erosion of the margins of the cortical bone (Fig. 1B). These findings suggested a subungual glomus tumor.

The tumor was completely excised. The location and size of the nodule shown by high-resolution MR imaging correlated well with the surgical findings. Erosion of the cortex was also observed at surgery. Histopathologic examination showed a small tumor with vascular spaces with a single layer of normal endothelial cells. Numerous cells were aligned in rows around the central lumen, which was lined with endothelial cells. No evidence of malignant growth was found. The diagnosis was glomus tumor.

Before the advent of MR imaging, conventional radiologic evaluation of glomus tumors was primarily limited to intraosseous tumors and soft-tissue tumors with secondary bone involvement. MR imaging has now made it possible to visualize soft-tissue tumors without bone erosion. Furthermore, with high-resolution MR imaging, the smallest soft-tissue tumors can be detected, allowing early diagnosis. This technique may help in detecting multiple glomus tumors preoperatively, thus permitting total excision and preventing relapse.

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Pneumocephalus Due to Barotrauma: CT Demonstration

Scuba diving has enjoyed a tremendous surge in popularity. Although the overall prevalence of diving-related CNS barotrauma is small, the increase in the number of dives performed each year will result in an increase in the number of cases of this disorder. Neurologic symptoms may range from minimal dysesthesias to complete quadriplegia, encephalopathy, or death. Divers affected by dysbaric injuries to the CNS can be clinically divided into two subsets: those with cerebral involvement, which is likely due to arterial gas embolization from pulmonary barotrauma, and those with spinal cord involvement, otherwise known as spinal cord compression sickness [1]. Pneumocephalus as a result of barotrauma during scuba diving has previously been reported only once [2]. The resulting intracranial air, as in our case, was mainly in the subarachnoid space. We discuss the CT findings and the possible cause.

A 31-year-old woman was scuba diving at 25 m underwater when she panicked after nearly exhausting her oxygen supply. According to her friend, she became confused and agitated. In a hurried ascent, she made no decompression stops. On surfacing, she had a major motor seizure and became unconscious with respiratory arrest. Despite cardiopulmonary assistance and gradual recompression, she remained unconscious, hypotensive, and quadriplegic. An unenhanced cranial CT scan (Fig. 1A) obtained 6 hr after the accident showed decreased differentiation between gray and white matter, with effacement of the cortical sulci. The subcortical white matter contained poorly defined areas of low attenuation. These findings

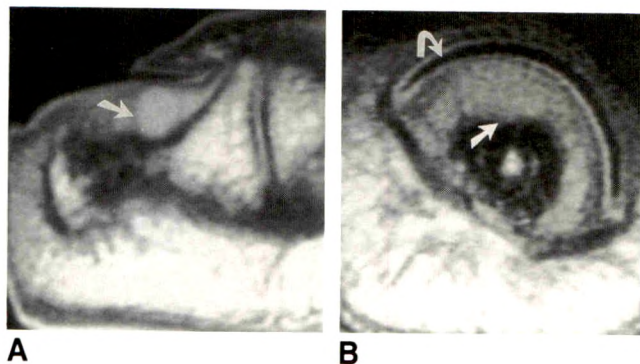


Fig. 1.—Subungual glomus tumor.

A, Sagittal proton density-weighted spin-echo MR image shows a homogeneous, well-defined nodule (arrow) dorsal to ungual phalanx diaphysis within dermis. Field of view: 50 mm horizontally, 25 mm vertically.

B, Axial T1-weighted spin-echo MR image shows smooth erosion (straight arrow) of margins of cortical bone. Nail is seen as a curved hypointense line (curved arrow). Field of view: 20×20 mm; slice thickness: 3 mm.

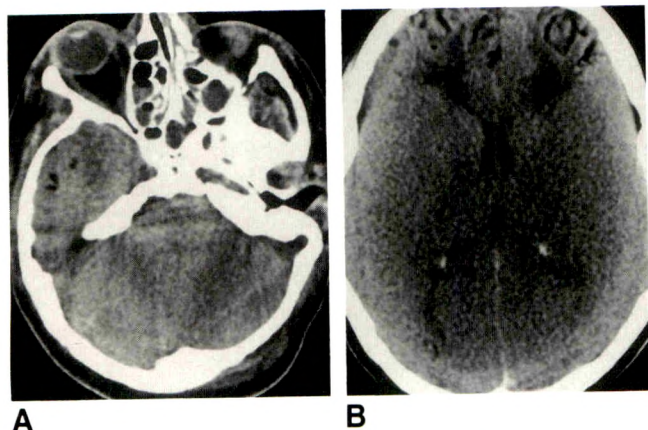


Fig. 1.—Pneumocephalus due to diving-related barotrauma in a 31-year-old woman.

A, CT scan obtained 6 hr after diving accident shows brain edema, subcortical areas of low attenuation, and large quantities of subarachnoid air.

B, CT scan obtained 7 hr after **A**, after hyperbaric oxygen recompression and adjunctive therapy, shows rapidly progressive brain edema with complete loss of differentiation between gray and white matter, which led to patient's death.

were more pronounced in the frontal lobes and the parietal operculum bilaterally. In addition, a large quantity of air was detected in the frontoparietal subarachnoid spaces. The patient was treated with hyperbaric oxygen recompression and adjunctive therapy. Subsequent CT (Fig. 1B) showed a decrease of subarachnoid air and a marked increase of cerebral edema with effacement of the basal cisterns and loosening of the contour of the fourth ventricle. Opacification of the sphenoid sinus, some of the ethmoid cells, and the left maxillary sinus with air-fluid level was present. One day after the accident, the patient died.

Pneumocephalus usually results from CNS trauma, neoplasm, infection, or iatrogenic causes such as surgery, lumbar puncture, or the insertion of venous or arterial catheters [3, 4]. Intracranial air may be intravascular, intraventricular, intradural, epidural, subdural, subarachnoid, or intraparenchymal. Air in the subarachnoid space results from trauma causing fracture of an air-containing cranial cavity and an associated dural tear, thus allowing communication with the subarachnoid space [3].

The intracranial air in our case was likely a result of barotrauma. Pneumocephalus associated with rapid changes in pressure has rarely been reported. In one case [2], a subdural collection of air resulted from mastoid disruption during scuba diving. Canavan et al. [4] reported a case of air in the dural sinus associated with barotrauma in an amateur pilot. During a hurried diving ascent without decompression stops, the expanding air in the paranasal sinuses cannot escape fast enough, and pathologic overpressure can introduce large quantities of air into the cranium. In our case, the subarachnoid air was presumably the result of leakage of air from the paranasal sinuses with associated dural tear. Accompanying elements in support of this theory are location of the air and the presence of sinus abnormalities.

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Extradural Schwannoma Manifested as an Expansile Vertebral Lesion

Spinal schwannomas and neurofibromas can enlarge the intervertebral foramen and cause scalloping of the vertebral body. We describe a case in which an extradural schwannoma eroded through the pedicle and vertebral body in a pattern resembling that of an expansile bone tumor.

A 41-year-old man had had lower back pain for 10 years. Physical examination showed diminished reflexes in the left knee and ankle but no weakness or loss of sensation. Plain radiographs of the lumbar spine showed a 4.5-cm radiolucent lesion with a sclerotic rim. The lesion expanded the L4 vertebral body and obliterated the left pedicle (Fig. 1A). MR images showed an enhancing extradural mass that expanded the vertebral body and lamina and destroyed the L4 pedicle (Fig. 1B). At surgery, a well-encapsulated extradural tumor was found attached to the left L4 nerve just distal to the nerve root ganglion. The mass was dissected off the dural sac, and the capsule was mobilized out of the vertebral body excavation. Pathologic examination showed schwannoma, a benign tumor of nerve sheath elements.

In an article on expansile vertebral bone lesions, Kumar et al. [1] did not include extradural schwannoma in their list, and this tumor is not mentioned in other sources of differential diagnosis. Osteoblastoma, aneurysmal bone cyst, and giant-cell tumor are among the tumors to be considered when a patient has an expansile lumbar lesion. Intraosseous vertebral schwannomas have been described but not as causing an expansile lesion. Other articles [2] on the CT appearance of schwannomas and neurofibromas have not reported an expansile pattern on CT or plain radiographs. An extradural

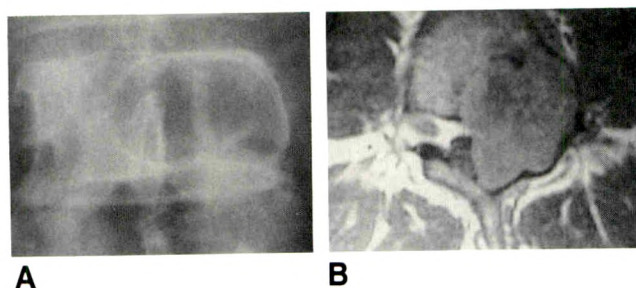


Fig. 1.—Extradural schwannoma.
A, Anteroposterior radiograph shows radiolucent mass expanding L4 vertebra and obscuring left pedicle.
B, Axial T1-weighted spin-echo MR image shows extradural mass expanding vertebral body and lamina.

schwannoma should be considered in the differential diagnosis of an expansile vertebral lesion.

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Letters to the Editor must not be more than two *double-spaced*, typewritten pages. One or two figures may be included. Abbreviations should not be used. Limit the number of authors to four, or we will list only the first three and add "and colleagues" to the end of the list. See Author Guidelines.

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Letters concerning a paper published in the *AJR* will be sent to the authors of the paper for a reply to be published in the same issue. Opinions expressed in the Letters to the Editor do not necessarily reflect the opinions of the Editor.

Erratum

The letter to the editor titled "Intramammary Lymph Node in the Lower Outer Quadrant Detected Mammographically," credited to K. Kevin Shamlou (*AJR* 1992;159:899) had two coauthors who were not cited: these are Barbara G. Steinbach, Department of Radiology, and N. Sisson Hardt, Department of Pathology, both of the University of Florida College of Medicine, Gainesville, FL 32610-0374.

Review of Current Literature

Initials and addresses of corresponding authors are provided in parentheses for each article so that the reader can obtain reprints directly. Abstracts are printed verbatim from each journal.

The New England Journal of Medicine

Localization of pancreatic endocrine tumors by endoscopic ultrasonography. Rösch T, Lightdale CJ, Botet JF, et al. (TR, II. Medizinische Klinik und Poliklinik der Technischen Universität München, Klinikum rechts der Isar, Ismaningerstr. 22, 8000 München 80, Germany). *N Engl J Med* 326(26):1721-1726, June 1992

Background. After a pancreatic endocrine tumor has been diagnosed on the basis of clinical signs and the results of laboratory tests, localization of the tumor by the usual imaging procedures fails in as many as 40 to 60 percent of patients. Endoscopic ultrasonography, a sensitive test for small carcinomas of the pancreas, might also be useful in patients with endocrine tumors of the pancreas that cannot be localized by conventional methods.

Methods. We studied 37 patients later shown to have 39 endocrine tumors of the pancreas who had negative results on transabdominal ultrasonography and CT. All the patients underwent endoscopic ultrasonography, and 22 also underwent selective angiography. All the tumors were confirmed by surgical excision and immunohistologic examination; they consisted of 31 insulinomas, 7 gastrinomas, and 1 glucagonoma, 0.5 to 2.5 cm (mean, 1.4 cm) in diameter. All but one of the patients were cured of their disease, as ascertained by at least six months of clinical and laboratory follow-up.

Results. Using endoscopic ultrasonography, we were able to localize 32 of the 39 tumors (sensitivity, 82 percent); no tumor was incorrectly localized. The size of the tumors was very similar (within 2 mm) to that predicted by endoscopic ultrasonography. Among the 22 patients who underwent both angiography and endoscopic ultrasonography, ultrasonography was significantly more sensitive than angiography for tumor localization (sensitivity, 82 percent vs. 27 percent). Among 19 control patients without pancreatic endocrine tumors, endoscopic ultrasonography was negative in 18 (specificity, 95 percent).

Conclusions. Endoscopic ultrasonography is a highly sensitive and specific procedure for the localization of pancreatic endocrine tumors. It should be considered for the preoperative localization of such tumors once the clinical and laboratory diagnosis has been established.

Risk of leukemia after chemotherapy and radiation treatment for breast cancer. Curtis RE, Boice JD Jr, Stovall M, et al. (REC, Executive Plaza North, Ste. 408, National Cancer Institute, Bethesda, MD 20892). *N Engl J Med* 326(26):1745-1751, June 1992

Background. Few studies have evaluated the late effects of adjuvant chemotherapy for breast cancer. Moreover, the relation between the risk of leukemia and the amount of drug given and the interaction of chemotherapy with radiotherapy have not been described in detail.

Methods. We conducted a case-control study in a cohort of 82,700 women given a diagnosis of breast cancer from 1973 to 1985 in five areas of the United States. Detailed information about therapy was obtained for 90 patients with leukemia and 264 matched controls. The dose of radiation to the active marrow was estimated from individual radiotherapy records (mean dose, 7.5 Gy).

Results. The risk of acute nonlymphocytic leukemia was significantly increased after regional radiotherapy alone (relative risk, 2.4), alkylating agents alone (relative risk, 10.0), and combined radiation and drug therapy (relative risk, 17.4). Dose-dependent risks were observed after radiotherapy and treatment with melphalan and cyclophosphamide. Melphalan was 10 times more leukemogenic than cyclophosphamide (relative risk, 31.4 vs. 3.1). There was little increase in the risk associated with total cyclophosphamide doses of less than 20,000 mg.

Conclusions. Although leukemia occurs in few patients with breast cancer, significantly elevated risks were linked to treatments with regional radiation and alkylating agents. Melphalan is a more potent leukemogen than cyclophosphamide or radiotherapy. Low risks were associated with the levels of cyclophosphamide in common use today. Systemic drug therapy combined with radiotherapy that delivers high doses to the marrow appears to enhance the risk of leukemia.

Diagnosis and staging of colonic tumors by conventional abdominal sonography as compared with hydrocolononic sonography. Limberg B (BL, 2nd Dept. of Internal Medicine, Klinikum Darmstadt, Academic Hospital of the University of Frankfurt, Grafenstrasse 9, 6100 Darmstadt, Germany). *N Engl J Med* 327(2):65-69, July 1992

Background. Ultrasonic examination has become increasingly important in the diagnosis of diseases of the gastrointestinal tract. In neoplastic diseases of the large intestine, however, the diagnostic value of conventional transabdominal sonography is limited. The purpose of this investigation was to determine whether the evaluation and staging of colonic tumors would be improved by the retrograde instillation of water into the colon in a procedure called hydrocolononic sonography.

Methods. Three hundred patients were examined in a prospective study in which both conventional transabdominal sonography and transabdominal hydrocolononic sonography were performed before the diagnosis was verified by colonoscopy. The indication for the examinations was abdominal pain, diarrhea, weight loss, or the presence of occult blood in a stool specimen.

Results. With the instillation of water into the colon, it was possible to display the colon sonographically from the rectosigmoid transition to the cecum in 97 percent of the patients examined. In addition to

permitting the evaluation of the colonic lumen, the procedure allowed the five layers of the colonic wall and the connective tissue surrounding the colon to be examined in detail. Only 9 of 29 carcinomas were diagnosed by conventional abdominal sonography (31 percent), whereas hydrocolonic sonography permitted the diagnosis of 28 (97 percent). No polyps could be detected by conventional abdominal sonography, whereas hydrocolonic sonography permitted the diagnosis of 38 of 42 polyps ≥ 7 mm (91 percent) and 3 of 12 polyps < 7 mm (25 percent). In addition, detailed evaluation of the structure of the bowel wall with hydrocolonic sonography permitted a more precise staging of colonic tumors.

Conclusions. Hydrocolonic sonography, a new diagnostic procedure, can facilitate the diagnosis and staging of colonic tumors.

Chest

Pretreatment staging evaluation in small cell lung carcinoma: a new approach to medical decision making. Chauvin F, Trillet V, Court-Fortune I, et al. (FC, Centre Leon Berard, 28 rue Laennec, Lyon, France 69008). *Chest* 102(2):497-502, Aug. 1992

The real need for extensive staging at the time of diagnosis is discussed in regard to small cell lung carcinoma. We performed a decisional retrospective analysis on a series of 182 patients, based on three staging steps: the first step included physical examination and routine biologic tests. The second step consisted of liver ultrasonography and needle aspiration of any clinically detectable tumor mass, and the third step included bone marrow examination, radionuclide bone scan, thoracic, abdominal, and brain CT scan. A stepwise multivariate logistic regression performed on 11 variables considered in the first step shows that a four-parameter model can predict the spread of the disease (limited or extensive): weight loss, performance status, and elevated LDH or alkaline phosphatase levels. Limited disease can be predicted in two ways: (1) elevated LDH with normal alkaline phosphatases, no weight loss, and good performance status, or (2) normal LDH and alkaline phosphatases. In this series, 28 percent of patients can be predicted as having extensive disease and can be treated with chemotherapy alone without chest irradiation. After the second step, the probability of disease being extensive is only 25 percent, and only 84 (46.15 percent) patients would need to undergo the third step of staging procedures (brain CT scan, bone marrow aspiration and biopsy, radionuclide bone scan) with this method. We conclude that a multistep approach represents a simple staging method and offers the advantage of harmlessness and lower costs for patients not to be evaluated in prospective clinical trials.

Circulation

Eighteen-year follow-up in the Veterans Affairs Cooperative Study of Coronary Artery Bypass Surgery for Stable Angina. The VA Coronary Artery Bypass Surgery Cooperative Study Group (P. Peduzzi, Cooperative Studies Program, Bldg. 35 [151A], VA Medical Center, West Haven, CT 06516). *Circulation* 86(1):121-130, July 1992

Background. The 18-year effect of bypass surgery compared with medical therapy on survival, incidence of myocardial infarction, and relief of angina was evaluated in 686 randomized patients with stable angina in the Veterans Affairs Cooperative Study of Coronary Artery Bypass Surgery.

Methods and Results. The primary treatment comparisons were made according to intent to treat; 44% of the entire medical cohort had bypass surgery during a median follow-up of 16.8 years. Overall 18-year survival rates were 33% for medicine compared with 30% for surgery ($p=0.60$). Survival rates for high-risk patients without left main disease, which had shown a significant advantage for surgical therapy up to 11 years, were 23% medicine versus 24% surgery for patients with three-vessel disease and impaired left ventricular function ($p=0.49$) and 22% versus 25% for those with multiple clinical risk factors ($p=0.12$). For patients with two-vessel disease, who had significantly better survival with medical therapy at 11 years, rates

were similar at 18 years in the two treatment groups (34% medicine versus 30% surgery, $p=0.9$). Cumulative 18-year myocardial infarction rates (fatal plus nonfatal) were 41% in medical and 49% in surgical patients (13% perioperative infarction rate), $p=0.15$. Nonfatal infarction rates were lower with medical than with surgical therapy (32% versus 44%, $p=0.015$), but fatal infarction rates were similar (14% medicine versus 13% surgery, $p=0.62$). The combined rate of myocardial infarction or death was also lower with medical therapy (75% versus 82%, $p=0.016$). In contrast, surgery reduced mortality after myocardial infarction by 35% at 10 years ($p<0.001$) but only by 13% at 18 years ($p=0.09$). The percent of medical and surgical patients who were angina-free was 3% versus 22% ($p<0.01$) at 1 year and 4% versus 12% ($p<0.001$) at 5 years compared with rates of 6% versus 5% ($p>0.50$) at 10 years and 3% versus 4% ($p>0.50$) at 15 years.

Conclusions. The benefits of coronary artery bypass surgery on survival, symptoms, and postinfarction mortality were transient and lasted fewer than 11 years. The benefits began to diminish after 5 years, when graft closure accelerated. Surgery was effective in reducing mortality only for patients with a poor natural history. Low-risk patients, who had a good prognosis with medical therapy, derived no survival benefit with surgical therapy at any time during the follow-up period. Regardless of risk, surgery also did not reduce the incidence of myocardial infarction or the combined incidence of infarction or death.

Does the new angiotensin converting enzyme inhibitor cilazapril prevent restenosis after percutaneous transluminal coronary angioplasty? Results of the MERCATOR Study: a multicenter, randomized, double-blind placebo-controlled trial. The Multicenter European Research Trial with Cilazapril after Angioplasty to Prevent Transluminal Coronary Obstruction and Restenosis (MERCATOR) Study Group (P. W. Serruys, Catheterization Laboratory, Thoraxcenter, Postbox 1738, 3000 DR Rotterdam, the Netherlands). *Circulation* 86(1):100-110, July 1992

Background. Cilazapril is a novel angiotensin converting enzyme inhibitor with antiproliferative effects in the rat model after balloon injury.

Methods and Results. We conducted a randomized, double-blind placebo-controlled trial to assess the effect of cilazapril in angiographic restenosis prevention after percutaneous transluminal coronary angioplasty (PTCA). Patients received cilazapril 2.5 mg in the evening after successful PTCA and 5 mg b.i.d. for 6 months or matched placebo. In addition, all patients received aspirin for 6 months. Coronary angiograms before PTCA, after PTCA, and at 6-month follow-up were quantitatively analyzed. In 94% of 735 recruited patients, PTCA was successful and all inclusion and exclusion criteria were met. For the per-protocol analysis, quantitative angiography after PTCA and at follow-up was available in 595 patients who complied with the treatment regimen (309 control, 286 cilazapril). The mean difference in minimal coronary lumen diameter between post-PTCA and follow-up angiogram (primary end point) was -0.29 ± 0.49 mm in the control group and -0.27 ± 0.51 mm in the cilazapril group. Clinical events during 6-month follow-up, analyzed on an intention-to-treat basis, were ranked according to the most serious clinical event ranging from death (control, two; cilazapril, three), nonfatal myocardial infarction (control, eight; cilazapril, 5), coronary revascularization (control, 51; cilazapril, 53), or recurrent angina requiring medical therapy (control, 67; cilazapril, 68) to none of the above (control, 224; cilazapril, 212). There were no significant differences in ranking.

Conclusions. Long-term angiotensin converting enzyme inhibition with cilazapril in a dose of 5 mg b.i.d. does not prevent restenosis and does not favorably influence the overall clinical outcome after PTCA.

Gastroenterology

Measurement of gastric emptying by magnetic resonance imaging in humans. Schwizer W, Maecke H, Fried M (WS, Division of

Gastroenterology PMU/CHUV, University Hospital, Lausanne, Switzerland). *Gastroenterology* 103:369-376, 1992

A new noninvasive radiation-free method to measure gastric emptying in humans was developed. The upper abdomen was recorded with a magnetic resonance imager after administration of a liquid meal containing Gadolinium tetraazacyclododecane tetraacetic acid as a magnetic resonance image (MRI) marker. Meal volumes, total gastric volumes, and secretory rates were measured. The MRI technique was validated simultaneously by the double indicator method in 5 healthy volunteers and in 5 patients with symptoms of disordered gastric emptying applying gamma camera scintigraphy and MRI in randomized order. Similar gastric meal emptying curves were obtained in volunteers and in patients by MRI and the reference methods as assessed by linear ($r > 0.90$; $P < 0.001$) and intraclass correlation analysis ($r > 0.905$) for $T_{1/2}$, areas under the curve, and percent of gastric meal retained. Furthermore, similar total gastric volumes and gastric secretory rates were measured by MRI and the double indicator technique. The new MRI method correctly reflected gastric emptying disorders in patients. Thus for the first time it is possible to combine these measurements of gastric functions in a single method and to relate them to gastric morphology visualized by the generation of three-dimensional images.

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Pancreatic and hepatic abscesses: a late complication in 10 patients with chronic pancreatitis. Ammann R, Münch R, Largiadèr F, Akovbiantz A, Marincek B (RA, Dept. of Medicine, University Hospital, Zurich, Switzerland). *Gastroenterology* 103:560-565, 1992

In this prospective long-term study of chronic pancreatitis ($n = 336$) over the last 3 decades, 10 patients with advanced calcific pancreatitis developed a sepsis associated with intra-abdominal abscesses (6 pancreatic, 4 hepatic). None of the known precipitating factors were present (e.g., no pancreatic necrosis or recent surgical/endoscopic interventions, no evidence of cholangitis). Nine of 10 patients had alcoholic chronic pancreatitis. Interestingly a pancreatojejunostomy in 9 of 10 patients had been performed up to 12 years previously. Cultures from abscess aspirates and/or blood were polymicrobial, mainly a mixed enteric flora in 8 patients. All patients recovered after an appropriate antibiotic therapy with or without drainage procedures. The pathogenesis of "spontaneous" abscess formation in advanced chronic pancreatitis and its relationship to pancreatojejunostomy remain to be established.

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Gastrointestinal Endoscopy

Local staging and assessment of resectability in carcinoma of the esophagus, stomach, and duodenum by endoscopic ultrasonography. Rösch T, Lorenz R, Zenker K, et al. (TR, Technical University Medical Clinic II, Klinikum rechts der Isar, Ismaningerstr. 22, DW-8000, Munich 80, Germany). *Gastrointest Endosc* 38:460-467, 1992

Eighty-eight patients with carcinoma of the esophagus ($N = 44$), stomach ($N = 41$), and duodenum ($N = 3$) who underwent surgery were pre-operatively examined by endoscopic ultrasonography (EUS). The ability of EUS to accurately predict the T stage and the N stage was 82% and 70% for esophageal carcinoma, 71% and 75% for gastric cancer, and 100% and 66% for duodenal malignancy. In esophageal carcinoma, the accuracy of T staging was only slightly lower in cases with non-traversable tumor stenoses (77%) compared with traversable carcinomas (84%). This was probably due to the fact that all non-traversable tumors were either in stage T3 or T4. The accuracy of EUS in predicting the stages T1 to T3, which correspond to R0 resectability (no macroscopic or microscopic tumor remains), was 92% for adenocarcinoma of the distal esophagus and 85% for gastric cancer. However, in squamous cell carcinoma of the esophagus, R0 resection was possible in only 66% of all cases, whereas EUS predicted an 84% R0 resection rate. In adenocarcinoma of the

distal esophagus and stomach, EUS prediction of stages T1 to T3 correlated well with the actual rate of R0 resection. These results show that EUS is a reliable diagnostic method for the local staging of upper gastrointestinal cancer. Its impact on treatment and hence on prognosis of patients with these malignancies has yet to be determined.

Delayed biliary drainage is common in asymptomatic post-cholecystectomy volunteers. Elta GH, Barnett JL, Ellis JH, Ackermann R, Wahl R (GHE, 3912 Taubman Center, Ann Arbor, MI 48109-0362). *Gastrointest Endosc* 38:435-439, 1992

A commonly used diagnostic criterion for sphincter of Oddi dysfunction is delayed drainage of contrast media from the bile ducts at endoscopic retrograde cholangiography (ERC), which is defined as the persistence of contrast >45 min after injection. We performed ERC in 11 asymptomatic post-cholecystectomy volunteers for the purpose of evaluating biliary drainage time. In an attempt to more accurately quantify emptying, concomitant scintigraphy was performed at the time of ERC and contrast drainage. Sufficient contrast mixed with technetium-99m sulfur colloid to completely fill out the intra-hepatic tree was injected (mean volume, 9 ml) and the volunteers remained in the prone position during imaging. The length of time from cholecystectomy, bile duct size, volume of contrast injected, and scintigraphic $T_{1/2}$ s did not correlate with drainage time at ERC. At 45 min after injection the degree of residual contrast filling was scored as: empty in three volunteers, almost empty in one, one-fourth full in 5, and one-half full in two. Therefore, 7 of the 11 asymptomatic volunteers (63%) had delayed drainage. Even if more stringent criteria for delayed drainage were used (ducts one-half filled), 2 of the 11 (18%) had abnormal drainage. The frequent occurrence of delayed drainage in these asymptomatic post-cholecystectomy volunteers challenges the validity of the 45-min delayed drainage criterion for sphincter of Oddi dysfunction.

The Journal of Bone and Joint Surgery

Comparison of orthoroentgenography and computed tomography in the measurement of limb-length discrepancy. Aaron A, Weinstein D, Thickman D, Eilert R (AA, University of Colorado Health Sciences Center, B202, 4200 E 9th Ave., Denver, CO 80262). *J Bone Joint Surg [Am]* 74A(6):897-902, July 1992

To determine the most accurate roentgenographic technique for the measurement of limb-length discrepancy, the twenty lower extremities of ten cadavers were measured with use of both orthoroentgenograms and lateral scout computed-tomographic scanograms. The actual anatomical limb length also was measured, to serve as a control. The effects of flexion of the knee joint, use of an external fixator, cost and time of the examination, and exposure to radiation also were determined.

No statistically significant difference in the measurements of the length of the femur was found between the two methods at neutral or at 15, 30, or 45 degrees of flexion of the knee. However, computed tomography was significantly more accurate than orthoroentgenography in the measurements of length of the tibia and of total length of the limb when the knee was flexed to 30 degrees or more ($p < 0.01$). The placement of an Ilizarov fixator did not alter the results.

The cost and time necessary to complete an examination were comparable for the two methods. However, computed tomography delivered only 20 per cent of the radiation method needed for orthoroentgenography.

Computed tomography is more accurate than orthoroentgenography for the measurement of limb-length discrepancy in patients who have a flexion deformity of the knee.

The Journal of Urology

Radiographic evaluation of adult patients with blunt renal trauma. Eastham JA, Wilson TG, Ahlering TE (JAE, Dept. of Urology, Univer-

sity of Southern California Medical Center, Los Angeles, CA). *J Urol* 148:266-267, Aug. 1992

Recent reports in the literature suggest that radiographic evaluation of the normotensive blunt trauma patient with microscopic hematuria is no longer necessary. Several facilities, however, including ours, continue to perform excretory urography (IVP) routinely in this setting. To evaluate further whether this practice is indicated, we retrospectively reviewed the records of 317 adults who presented to our facility between May 1986 and December 1989 after blunt trauma with resultant microscopic hematuria but no shock. All patients were radiographically assessed with an IVP. Of the 317 studies 29 (9%) had an abnormal result, including 28 with renal contusion and 1 with a nonfunctioning kidney (in which case further evaluation revealed a congenitally absent kidney). No significant urological injury was identified. Thus, no injury would have been missed if a policy of observation had been followed in these patients. Our data support other reports in the literature that radiographic staging is not necessary in the adult blunt trauma patient with microscopic hematuria but no shock.

The Journal of Pediatrics

Clinical application of ultrasonography in the diagnosis of intussusception. Bhisitkul DM, Listernick R, Shkolnik A, et al. (DMB, Division of General Academic and Emergency Pediatrics, Children's Memorial Hospital, 2300 Children's Plaza, Box 16, Chicago, IL 60614). *J Pediatr* 121:182-186, 1992

Sixty-five consecutive patients seen in a pediatric emergency department, in whom the diagnosis of intussusception was considered, had an ultrasound examination of the abdomen before a barium enema. The mean age of the patients was 1.7 years (range 2 weeks to 5 years). Intussusception was detected by ultrasonography in all 20 cases proved by barium enema. There were three false-positive ultrasound results (sensitivity = 100%, confidence interval (CI) = 86% to 100%; specificity = 93%, CI = 86% to 96%). Normal findings on ultrasonography correlated with a negative barium enema results in 42 of 42 cases (negative predictive value = 100%, CI = 94% to 100%). No intussusception was missed by ultrasonography. To determine which patients would most benefit from ultrasonography, we divided patients into either a high-risk group (81% with intussusception) or a low-risk group (14% with intussusception) on the basis of clinical symptoms ($p < 0.01$). If each high-risk child had a barium enema and each low-risk child had an ultrasound study as their initial diagnostic test, 89% of the patients in this study would have undergone only one examination. We conclude that ultrasonography can be used as a rapid, sensitive screening procedure in the diagnosis or exclusion of childhood intussusception. Children considered at low risk of having intussusception on the basis of clinical symptoms should initially have an ultrasound examination; patients at high risk should have an immediate barium enema.

Surgery Obstetrics and Gynecology

Treatment of calculi of the common bile duct. Schwab G, Pointner R, Wetscher G, Glaser K, Foltin E, Bodner E (GS, Dept. of Surgery II, University Hospital, Anichstr. 35, A6020 Innsbruck, Austria). *Surg Obstet Gynecol* 175:115-120, 1992

Endoscopic sphincterotomy (EST) is regarded as an alternative therapeutic approach to the surgical treatment of choledocholithiasis. To clarify the indication for each of these two methods, a prospective study has been performed comparing patients with calculi of the common bile duct who had undergone endoscopic or surgical treatment. Mortality, morbidity and stone clearance were used as criteria for the evaluation of the dependence of age on results achieved by the two modalities. Of 306 patients with choledocholithiasis, 199 underwent surgical exploration of the duct and 107 underwent endoscopic sphincterotomy. Patients who were more than 60 years of

age and had previously undergone cholecystectomy underwent endoscopic sphincterotomy. All other patients had surgical treatment. There were no significant differences among the two groups with regard to mortality rates. The incidence of relevant complications as well as the incidence of surgical revisions related to postoperative complications in the operation group was, however, significantly higher ($p < 0.05$). In contrast with this, the incidence of retained stones was significantly lower ($p < 0.01$) in the group that underwent surgical treatment (2.5 percent) than in the group that had endoscopy (11.2 percent). When assessing the results in terms of stone clearance, complications and mortality rates, findings seem to indicate that a safe limit for the application of surgical treatment would be 60 years of age, whereas older patients should be primarily considered as candidates for EST.

Journal of Thoracic Imaging

Thin-rim enhancement in Gd-DTPA-enhanced magnetic resonance images of tuberculoma: a new finding of potential differential diagnostic importance. Sakai F, Sone S, Maruyama A, et al. (FS, Dept. of Radiology, School of Medicine, Shinshu University, Asahi, Matsumoto 390, Japan). *J Thorac Imaging* 7(4):64-69, 1992

The article describes rim enhancement seen on Gd-DTPA-enhanced magnetic resonance (MR) images of two patients with tuberculoma. Pathologic examination of the surgical specimens disclosed that the peripheral portion of the tuberculoma, which showed contrast enhancement, was composed mainly of a fibrous capsule and epithelioid granulomas and that the central zone, which showed no contrast enhancement, was composed of caseous necrotic material. In a retrospective study of MR images from 20 consecutive cases of surgically proven bronchogenic carcinoma, none showed a thin enhancing rim on postcontrast MR images. Although confirmation of these findings must await further experience, the postcontrast MR findings described here may prove to be of value in distinguishing tuberculoma and possibly other granulomatous lesions from bronchogenic carcinoma.

Journal of Ultrasound in Medicine

Sonographic scoring index for prenatal detection of chromosomal abnormalities. Benacerraf BR, Neuberger D, Bromley B, Frigoletto FD Jr (BRB, Diagnostic Ultrasound Associates, 333 Longwood Ave., Boston, MA 02115). *J Ultrasound Med* 11:449-458, Sept. 1992

Current indications for cytogenetic evaluation leave the majority of Down syndrome fetuses undetected. Using advanced maternal age and low maternal serum alpha-fetoprotein (AFP) levels as criteria, only 40% of fetuses with Down syndrome (trisomy 21) are identified (positive predictive value, 0.4% to 1%). We evaluate the sonographically detectable physical features of second trimester fetuses to determine whether these features are more sensitive and specific than maternal age for detecting fetuses with abnormal karyotypes.

From March 1 to September 1, 1991, more than 5,000 fetuses between 14 and 20 weeks of development were referred for genetic amniocentesis because of advanced maternal age or abnormal AFP levels. Forty-three of these 5,000 fetuses were later found to have autosomal trisomies by karyotype (32 with trisomy 21, nine with trisomy 18, and two with trisomy 13). A sample of 588 consecutive normal fetuses from the total of more than 5,000 amniocenteses performed during this period of time was used as our control group for statistical analysis. The sonographic features of these 588 normal second trimester fetuses and the 43 trisomic fetuses recorded prospectively prior to knowledge of the karyotype were evaluated statistically. The femur and humerus lengths, nuchal fold, renal pelvic dimension, and major structural defects were compared in the normal and trisomic fetuses. On the basis of our results, a weighted sonographic score was developed to optimize the detection of fetuses at risk for aneuploidy.

Using our previously published formulas and criteria for a short femur and humerus, 17/32 (53%) fetuses with Down syndrome and 23/588 (3.9%) of the normal fetuses were identified. Twenty two of 32 Down syndrome fetuses (69%) and 2/588 (0.34%) of normals had a nuchal fold ≥ 6 mm, and 11 of 32 Down syndrome fetuses and all those with trisomies 18 and 13 had a major anomaly detected sonographically. The following scoring system was developed for the detection of aneuploidy: nuchal fold = 2, major structural defect = 2, and short femur, short humerus, and pyelectasis = 1 each. Selecting fetuses with a score of ≥ 2 would identify 26/32 (81%) Down syndrome fetuses, and 9/9 (100%) and 2/2 (100%) fetuses with trisomies 18 and 13, respectively, but only 26/588 (4.4%) of the normal fetuses.

Using the sonographic score of 2 results in a positive predictive value for a 1/250 risk group of 6.87% for identifying Down syndrome fetuses and 7.25% for all three trisomies. For the 1/500 and 1/1,000 risk groups, the positive predictive values are 3.75% and 1.91%, respectively, for identifying the three trisomies. Sonographic features suggesting aneuploidy appear more effective in identifying affected fetuses than advanced maternal age.

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Journal of Computer Assisted Tomography

MRI and ultrasound detection of asymptomatic thyroid nodules in hyperparathyroidism. Funari M, Campos Z, Gooding GAW, Higgins CB (CBH, Dept. of Radiology, Box 0628, University of California at San Francisco, San Francisco, CA 94143). *J Comput Assist Tomogr* 16(4):615-619, July/Aug. 1992

A retrospective MRI and ultrasound (US) study of 50 patients with hyperparathyroidism and no history of thyroid disease was done. The purpose was to compare the sensitivity of both methods in the detection of asymptomatic thyroid nodules, as well as to determine the prevalence of thyroid abnormalities in patients with hyperparathyroidism. All the patients underwent MR and 33 were also studied by high-resolution US. Magnetic resonance imaging was performed on

a 1.5 T unit, using T1- (500-700/20) and T2- (2,000/20 and 70) weighted images. Axial sections (5 mm with a 1 mm interval between them) were obtained along the neck. Ultrasonography was performed using a 10 MHz linear array transducer. The prevalence of thyroid nodules was 46% in the 50 patients studied by MR imaging. In the subgroup of patients studied by both methods, US depicted nodules in 48% of patients, and MR depicted nodules in 45%. Magnetic resonance imaging and US detected a high frequency of thyroid nodules in patients with hyperparathyroidism. This high frequency makes the detection of an intrathyroidal parathyroid adenoma problematic.

Knee joint hyaline cartilage defects: a comparative study of MR and anatomic sections. Hodler J, Berthiaume MJ, Schweitzer ME, Resnick D (DR, Dept. of Radiology, Veterans Affairs Medical Center [114], 3350 La Jolla Village Dr., San Diego, CA 92161). *J Comput Assist Tomogr* 16(4):597-603, July/Aug. 1992

The value of routinely used MR sequences in the detection of focal changes of femorotibial articular cartilage was studied. T1-weighted, proton density, and T2-weighted SE as well as gradient echo images were acquired in 20 cadaveric knees (56-88 years old, mean 73.8 years). Three hundred five coronal and sagittal (3 mm) anatomic sections were prepared, and 82 areas of cartilage defects were identified. Initially, in an unblinded fashion, correlation of MR scans and anatomic sections were performed. Fifty-nine lesions (72.0%) were detectable on T1-weighted images, 57 (70.0%) with meniscal windowing, 49 (60.0%) on proton density images, 56 (68.3%) on T2-weighted images, and 54 (65.9%) on gradient echo images. Sixty-eight (83.0%) were visible on at least one type of imaging sequence. Most defects presented as a focus of abnormal signal. Subsequently, images of a subset of 35 pathologic and 35 normal cartilage surfaces were blindly evaluated by two osteoradiology fellows. Sensitivity was 71.4% for the detection of focal cartilage changes, specificity was 68.6%, and accuracy was 70.0%. We conclude that the value of those MR sequences that are routinely used in the analysis of internal derangements of the knee in the detection of focal defects of the hyaline cartilage is limited.

News

Midwinter Radiological Conference

The Los Angeles Radiological Society (LARS) is sponsoring the 45th annual Midwinter Radiological Conference, Jan. 15–17, 1993, at the Century Plaza Hotel, Los Angeles. Two special 1-day seminars, one on nuclear medicine and one on cardiovascular and interventional radiology, will be offered currently with Saturday's program. Other seminars, lectures, and workshops will cover four subject areas: MR imaging and neuroradiology, musculoskeletal imaging, chest imaging, and breast imaging. Faculty: J. Beltran, E. Hendrick, D. Kopans, W. Kucharczyk, T. McNamara, C. Ravin, J. Ross, D. Schwarten, E. Sickles, R. Webb, and 24 additional workshop and seminar speakers. Category 1 credit: up to 16.75 hr. Fee (3 days/2 days/1 day): physicians, \$450/\$405/\$225; LARS members, \$225/\$175/\$125; residents, \$150/\$125/\$100; LARS resident members and all technologists, \$125/\$100/\$75. Information: Los Angeles Radiological Society—MWRC, P. O. Box 91215, Los Angeles, CA 90009-1215; (310) 827-9078 or (800) LARS-013.

Duke Radiology Winter Postgraduate Course

The Dept. of Radiology, Duke University Medical Center, is sponsoring the Duke Radiology Winter Postgraduate Course, Feb. 8–12, 1993, in Aspen, CO. The course will cover clinically oriented diagnostic radiology, including nuclear medicine, thoracic imaging, neuroradiology, musculoskeletal imaging, and MR imaging. Course director: H. Dirk Sostman. Category 1 credit is pending. Fee: \$575. Information: Debbie Sykes, Dept. of Radiology, Box 3808, Duke University Medical Center, Durham, NC 27710; (919) 660-2711, ext. 5228.

International Course on Epidemiology of Nutrition and Cancer

The International Agency for Research on Cancer (IARC), World Health Organization, is organizing a course on the epidemiology of diet, nutrition, and cancer, March 1–12, 1993, at the IARC, Lyon, France. Main topics will include methodology of dietary assessment for epidemiologic studies; design and methodology of epidemiologic studies on nutrition and cancer; statistical methods in the epidemiology of nutrition and cancer; biomarkers of diet and nutritional status; methodological issues in research on hormones, diet, and cancer; practical exercises in the analysis of epidemiologic data; and cancer,

cardiovascular diseases, and diet. The working language of the meeting will be English. The course will be followed by the Ole Møller Jensen Memorial Symposium on Nutrition and Cancer, March 15–17, sponsored by the IARC and the International Union of Nutritional Sciences. Participants in the epidemiologic course will be welcome to attend the symposium at no charge. Course director: Elio Riboli; Faculty: F. Berrino, M. Hills, R. Kaaks, J. Little, P. Pietinen, J. Potter, D. Southgate, and W. Willett. Fee: no charge; some financial support will be available for a limited number of selected participants. Closing date for receipt of applications is December 15, 1992. Information: The Unit of Education and Training, International Agency for Research on Cancer, 150, cours Albert Thomas, F-69372 Lyon Cedex 08, France.

Interactive Surgery and Imaging of Paranasal Sinuses, Skull Base, Brain, and Spine

The Depts. of Radiology, Neurosurgery, and Otolaryngology–Head and Neck Surgery, The Johns Hopkins University School of Medicine, is sponsoring Interactive Surgery and Imaging of Paranasal Sinuses, Skull Base, Brain, and Spine, March 14–17, 1993, at the Silvertree Hotel, Snowmass Village, CO. The focus of the conference will be the diagnosis and treatment of diseases of the nasal cavity, skull base, spine, and brain. Topics to be discussed will be of interest to both surgeons and radiologists. Audience participation through case presentation will be emphasized, thus providing a practical problem-solving approach. Category 1 credit: 16 hr. Fee: physicians, \$475; residents and fellows, \$300. Information: Program Coordinator, The Johns Hopkins Medical Institutions, Office of Continuing Education, Turner Bldg., 720 Rutland Ave., Baltimore, MD 21205; (410) 955-2959.

Orthopedic Radiology 1993

The Dept. of Radiology, Brigham and Women's Hospital, and Harvard Medical School will present Orthopedic Radiology 1993, March 22–24, 1993, at the Ritz-Carlton Hotel, Boston. Program director: Barbara Weissman. Category 1 credit: approximately 22 hr. Fee: physicians, \$500; residents, fellows, and technologists, \$350. Information: Harvard Med-CME, P. O. Box 825, Boston, MA 02117; (617) 432-1525.

Ultrasound 1993

The Dept. of Radiology, Brigham and Women's Hospital, and Harvard Medical School will present the 18th annual postgraduate course, Ultrasound 1993, March 28–31, 1993, at the Westin Hotel, Copley Place, Boston. Special features will be Basics of Ultrasound Day, March 28th, and Obstetrical Ultrasound Day, March 29th. Program directors: Peter M. Doubilet and Carol B. Benson. Category 1 credit: approximately 27 hr. Fee: physicians, \$550; residents, fellows, and technologists, \$375; Basics of Ultrasound Day only, \$150; Obstetrical Ultrasound Day only, \$175. Information: Harvard Med-CME, P. O. Box 825, Boston, MA 02117; (617) 432-1525.

General Radiology Review Course

The Dept. of Radiological Sciences, University of California, Los Angeles, will present General Radiology Review Course, March 28–April 2, 1993, at the Doubletree Hotel, Marina Del Rey, CA. The course will include the latest clinical information on breast imaging, musculoskeletal imaging, gastrointestinal imaging, genitourinary imaging, head and neck imaging, neuroradiology, and sonography. Course directors: Zoran Barbaric and Poonam Batra. Category 1 credit (pending): 40 hr. Fee: \$425. Information: Mila Wayne, Dept. of Radiological Sciences, UCLA Medical Center, 10833 Le Conte Ave., BL-428 CHS, Los Angeles, CA 90024-1721; telephone: (310) 206-7435; fax: (310) 825-9812.

National Council on Radiation Protection and Measurements Annual Meeting

The 29th annual meeting of the National Council on Radiation Protection and Measurements will be held April 7–8, 1993, at the Crystal City Marriott, Arlington, VA. The title of the principal scientific session is "Radiation Science and the Public: Can the Gap Be Bridged?" Information: National Council on Radiation Protection and Measurements, 7910 Woodmont Ave., Ste. 800, Bethesda, MD 20814; telephone: (301) 657-2652 or (800) 229-2652; fax: (301) 907-8768.

Clinical Nuclear Medicine 1993

Harvard Medical School and the Joint Program in Nuclear Medicine at Beth Israel Hospital, Brigham and Women's Hospital, Children's Hospital, Dana-Farber Cancer Institute, and Brockton/West Roxbury Veterans Affairs Medical Center will present the 17th annual postgraduate course, Clinical Nuclear Medicine 1993, April 13–16, 1993, at the Westin Hotel, Copley Place, Boston. Program director: William D. Kaplan. Category 1 credit: approximately 25 hr. Fee: physicians, \$550; residents, fellows, and technologists, \$375. Information: Harvard Med-CME, P. O. Box 825, Boston, MA 02117; (617) 432-1525.

International Society of Lymphology Congress

The 14th international congress of the International Society of Lymphology will be held Sept. 20–26, 1993, in Washington, DC. Information: M. H. White, M.D., Dept. of Surgery, Rm. 4406, University of Arizona, College of Medicine, 1501 N. Campbell Ave., Tucson, AZ 85724; telephone and fax: (602) 626-0822.

The American Board of Radiology Examinations

Written examinations for the American Board of Radiology (ABR) are scheduled for Sept. 23–24, 1993. Oral examinations will be held at the Executive West Hotel in Louisville, KY, June 7–10, 1993. The ABR will accept applications for admission to the examinations after July 1, but no later than Sept. 30, in the year *preceding* the year in which the examination is to be taken. For application forms and further information: Office of the Executive Director, The American Board of Radiology, 2301 W. Big Beaver Rd., Ste. 625, Troy, MI 48084.

Meeting and Course Review

For the reader's convenience, a summary of upcoming meetings and courses is provided. Detailed listings are given in the *AJR* issue given in parentheses.

Visiting Fellowships in Interventional Radiology, times arranged, Baltimore (Sept)

Preceptorships in Ultrasound, times arranged, Baltimore (Sept)

MRI Visiting Fellowships at UCLA, Dec. 7–11, Los Angeles (Sept 1991)

CT/MRI Head to Toe, Dec. 14–19, New York City (Oct)

Postgraduate Imaging Seminar, Dec. 28, 1992–Jan. 1, 1993, Maui, HI (Sept)

Holiday Imaging Update, Dec. 28, 1992–Jan. 1, 1993, Aspen, CO (Sept)

The Complete MRI Course, Jan. 4–8, 1993, Maui, HI (Sept)

Musculoskeletal MR Course, Jan 4–8, 1993, Naples, FL (Oct)

Society of Uroradiology Annual Meeting, Jan. 9–15, 1993, Naples, FL (Oct)

Advanced Seminars in Diagnostic Imaging, Jan. 13–15, 1993, Feb. 24–27, 1993, and April 15–17, 1993, Laguna Niguel, CA (Nov)

Robert D. Moseley, Jr. Award, deadline for submissions, Jan. 15, 1993 (Oct)

Interventional Radiology Update, Jan. 16–17, 1993, Laguna Niguel, CA (Oct)

Society of Gastrointestinal Radiologists Annual Meeting, Jan. 17–22, 1993, Scottsdale, AZ (Sept)

Neuroradiology Update, Jan. 18–20, 1993, Laguna Niguel, CA (Oct)

Breast Imaging Update, Jan. 21–24, 1993, Laguna Niguel, CA (Oct)

Seminars in MRI, Jan. 23–30, 1993, Vail, CO (Nov)

Breast Imaging Course, Jan. 25–28, 1993, Naples, FL (Oct)

International Symposium on MR Imaging, Jan. 27–31, 1993, Garmisch-Partenkirchen (Bavaria), Germany (Oct)

Big Sky Radiology Conference, Jan. 31–Feb. 4, 1993, Big Sky, MT (Nov)

Computed Body Tomography 1993—The Cutting Edge, Feb. 4–7, 1993, Orlando, FL (Oct)

U. B. C. Practical Radiology at Whistler, Feb. 6–12, 1993, Whistler/Blackcomb Mountain, B.C. (Oct)

Current Topics in Diagnostic Imaging, Feb. 8–12, 1993, Cerromar Beach, Puerto Rico (Nov)

Diagnostic Imaging Update, Feb. 15–19, 1993, Palm Beach, FL (Oct)

Sun Valley Imaging Meeting, Feb. 20–27, 1993, Sun Valley, ID (Oct)

Intermountain Imaging Conference, Feb. 20–27, 1993, Snowmass, CO (Nov)

MRI Update 1993, Feb. 22–26, 1993, La Quinta, CA (Oct)

Diagnostic Imaging Update, Feb. 22–26, 1993, Maui, HI (Oct)

Magnetic Resonance Imaging, Feb. 22–26, 1993, Naples, FL (Oct)

Positron Emission Tomography, Feb. 28–March 2, 1993, Dana Point, CA (Oct)

Society of Computed Body Tomography and Magnetic Resonance Annual Course, March 1–5, 1993, Lake Buena Vista, FL (Nov)

Musculoskeletal Imaging for Orthopedic Surgeons and General Radiologists, March 1–5, 1993, St. Thomas, U.S. Virgin Islands (Nov)

San Diego Postgraduate Magnetic Resonance Imaging Course, March 8–12, 1993, San Diego (Nov)

PET and SPECT Imaging of Living Brain Chemistry, March 10–12, 1993, Baltimore (Nov)

MRI Workshop in Hawaii, March 21–26, 1993, Maui, HI (Nov)

International Diagnostic Course in Davos, March 27–April 2, 1993, Davos, Switzerland (Oct)

CIRSE and SCVIR Annual Meeting, June 20–25, 1993, Budapest, Hungary (Oct)

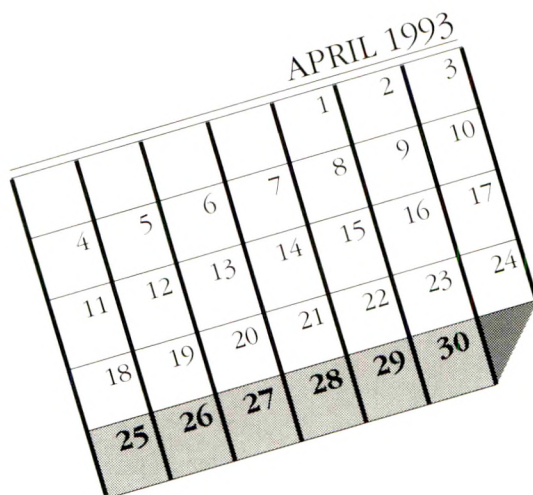
World Association of Sarcoidosis and Other Granulomatous Disorders Meeting, Sept 8–11, 1993, Los Angeles (Nov)

AJR carries announcements of courses, symposia, and meetings of interest to its readers if received a minimum of 5 months before the event. There is no charge; receipt of items by the *AJR* Editorial Office is not acknowledged. Submit items for publication typed double-spaced. Provide title, date, location, brief description, sponsor, course directors, fees, category I credit, and address and telephone number for additional information. Faculty from the host institution will not be listed. Guest faculty names will appear **only** if initials are provided. Mail news items to *AJR* Editorial Office, 2223 Avenida de la Playa, Suite 103, La Jolla, CA 92037-3218.

American Roentgen Ray Society

93rd Annual Meeting, San Francisco, CA

Mark Your Calendar Now!



The American Roentgen Ray Society will return to San Francisco in 1993, and plans are already underway for what promises to be an educationally fulfilling and socially enjoyable week in the city by the bay. Look for the San Francisco logo in the next several issues of the *AJR* for updated meeting information. 

Categorical Course

The topic of the 1993 Categorical Course is Ultrasound. A summary of topics and faculty for this course will appear in the February 1993 issue of the *AJR*.

Refresher Courses

Plans are underway to present at least 60 instructional courses on various topics of interest to the radiology community. A summary of these courses will be included in the February *AJR*. Early registration is strongly suggested, as these courses fill up quickly.

Residents' Award Papers

The society offers three cash awards for the best scientific papers prepared by residents in radiology. The President's Award has a cash prize of \$2,000, and there are two Executive Council Awards with a cash prize of \$1,000 each. The winners of these three awards are invited to present their papers during the opening ceremonies at the annual meeting. Papers must be submitted by February 12, 1993, for consideration in this competition. For additional information on these awards, contact the ARRS administrative offices at 1-800-438-2777.

Local Arrangements

The San Francisco area offers many opportunities for sightseeing, shopping and entertainment. Check the February *AJR* for detailed information on local tours developed especially for ARRS meeting attendees.

Registration and Hotel Reservations

All meeting activities will take place in the beautiful new San Francisco Marriott, centrally located on Market Street. The society has negotiated special room rates for meeting attendees, and the February *AJR* will contain meeting registration and hotel reservation forms. As in previous years, early registration is strongly suggested.

Travel

The society will make arrangements with United Airlines and a major car rental firm for preferred rates for meeting attendees. Taking advantage of these special rates benefits both you and the society - you save money on your reservations, and the society receives discounts to send staff and supplies to the meeting. Plan now to check the February issue of the *AJR* for details.

Classified Advertisements

Positions Available

GADSDEN RADIOLOGY ASSOCIATES is a 3-member radiology group seeking a fourth board-certified/eligible radiologist. Gadsden Radiology covers Baptist Memorial Hospital, a 250-bed hospital performing more than 55,000 radiologic exams/yr. All radiologic modalities are available, including state-of-the-art CT, SPECT, nuclear medicine, special procedures, and MRI. Gadsden Radiology Associates also covers their private office, imaging center, and a breast center. Teleradiography is used for call. Gadsden, AL, is a safe, clean city centrally located on the Coosa River approximately 1 hr from Birmingham, 90 Min. from Chattanooga, and 2 hrs from Atlanta, GA. Salary and vacation are excellent. Health insurance and malpractice is paid. Interested candidates contact Homer A. Spencer, M.D., 401 Bay Street, Gadsden, AL 35999; (205) 543-3200, or fax (205) 546-7908. 7-1ap

CENTRAL WISCONSIN—Established radiology group in independent practice is seeking 2 additional radiologists for growing practice in central Wisconsin. All imaging modalities. Competitive first yr salary with full partner status available second yr. Full benefits. Excellent schools, recreation, and quality of life. Contact David E. Enerson, M.D., 900 Illinois Ave., Stevens Point, WI 54481; (715) 346-5140 or Andrew M. Lucas, M.D., 410 Dewey St., Wisconsin Rapids, WI 54495-8080; (715) 423-6060. 12xa

ISRAEL, DIAGNOSTIC RADIOLOGY—Opportunities for 3- to 4-wk or longer working vacations in a number of Israeli medical centers, on a volunteer basis. Positions varied, arrangements flexible. For information contact Jonathan H. Fish, M.D., 1844 San Miguel Dr., #302, Walnut Creek, CA 94596; (510) 947-0560. 8-10xa

PARTNERSHIP POSITION IN PALM SPRINGS, CA—Well-established, 9-member group has openings for 2 board-certified radiologists. A physician with a strong background in MRI is sought as director of the section of MRI. The other position requires a physician with mammography experience to direct imaging in the breast health section of a new comprehensive cancer center. The group covers a 350-bed hospital and 2 offices in a desirable, rapidly expanding area of southern California. MRI facilities include 1.5-T Picker Vista HPQ with MRA package, ViStar imaging computer, and 1.5-T GE Signa. Other equipment includes 3 CT, a Cemax image processor, 2 Acuson color-flow Doppler ultrasound, 4 nuclear cameras including 2 SPECT, and all other diagnostic modalities. Ground has just been broken on a new 25,000 sq. ft. radiology wing, which will be furnished with state-of-the-art equipment. New trauma center, cancer center, and rehab hospital being built. Excellent compensation and benefits package leading to full partnership. Beaches and large-city amenities of Los Angeles only 2 hrs away. Yr-round sunny weather. Ample free time to enjoy southern California and the unparalleled recreational opportunities offered by the resort community of Palm Springs. Direct inquiries to Curtis E. Manning, M.D., Desert Hospital, Dept. of Radiology, 1150 N. Indian Canyon Dr., Palm Springs, CA 92262. 12xa

SUPERB PARTNERSHIP POSITION IN LAS VEGAS—Rapidly expanding 7-member group practice covering 2 full-service imaging centers and a small hospital has an immediate opening. We are looking for an additional board-certified radiologist with an uncommon dedication to excellence in patient care. Our outpatient facilities include 2 MR, 2 CT, angio with a 4-bed recovery area, 5 ultrasound, 5 mammography, 3 SPECT, plus R&F. This is an excellent opportunity for a partnership position with a well-respected group in a growing community. Please send CV to Dr. Mark Winkler, SDMI, 2950 S. Maryland Pkwy., Las Vegas, NV 89109. 3-2ap

SAN ANTONIO, TEXAS—Large group covering multiple hospitals and outpatient facilities seeks radiologists with angiography skills. Send CV to Search Committee, M&S X-Ray Associates, P.O. Box 15920, San Antonio, TX 78212-9510. 7-12ap

SOUTH CENTRAL FLORIDA—Immediate opening for board-certified (or eligible with intention to certify), Florida licensed general diagnostic radiologist. Four radiologists are now covering 3 hospitals totaling 250 beds as well as private diagnostic office with mammography. Onsite MRI at 1 hospital and mobile unit at another. Expertise in all modalities including interventional and angiography. Competitive package including early partnership. Send CV to Lawrence S. Ross, M.D., Radiology Consultants, P.A., 114 Medical Center, Sebring, FL 33870. 12xa

CENTRAL NEW JERSEY, IMMEDIATE OPENING—Full-time and part-time radiologists with fellowship training or equivalent experience in vascular/interventional and/or in MR imaging to join 6-member group. Must be willing to do other aspects of diagnostic radiology, mammography, ultrasound, CT, and nuclear medicine. Practice includes a 340-bed community hospital, a private radiology office, and an MRI facility. Area is within a 10-mi. radius of Princeton and is near New York City and Philadelphia. Competitive salary, excellent benefits, and partnership opportunity. Send CV or call Margaret M. Beck, Business Manager, 2127 Hamilton Ave., Trenton, NJ 08619; (609) 587-9410. 12xa

MAINE—BC/BE diagnostic radiologist with MRI and/or interventional skills. Join well-established multidimensional group. Associate leading to partnership. Competitive financial package. Family oriented small city. Business and cultural center. Major university. One hr to coast. Easy access to ski areas. Send CV to New England Health Search, 63 Forest Ave., Orono, ME 04473; (207) 866-5680. 12xa

DIAGNOSTIC RADIOLOGIST with skills in CT, MR, interventional, ultrasound, and nuclear medicine needed to join group of 8 board-certified radiologists. Growing practice in eastern Washington at a 228-bed hospital, a new multimodality imaging center and 1 private office. Potential for long-term practice is excellent. Top-notch school system, including 3 first-rate universities. Excellent hunting, fishing, boating and skiing. Contact Eric W. Koelsch, N. 5901 Lidgerwood, Ste. 18B, Spokane, WA 99207; (509) 487-1264. 8-1ap

VASCULAR/INTERVENTIONAL RADIOLOGIST—The University of Arizona Dept. of Radiology is recruiting a fellowship-trained vascular/interventional radiologist to join the faculty at the assistant associate professor level. Facilities at the University Hospital (300-bed) and Tucson Veteran's Hospital (300-bed) are state-of-the-art. Income is based on AAMC guidelines, but is negotiable. Contact Gerald D. Pond, M.D., Head, Section of Vascular and Interventional Radiology, University of Arizona Health Sciences Center, Tucson, AZ 85724; (602) 626-6794. Women and minorities are encouraged to apply. The University of Arizona is an EEO/AA employer. Applications will be accepted until position is filled. 12xa

NW ROCKY MOUNTAINS—Highly respected 8-person group with strong subspecialty interests seeks highly qualified radiologist. Fellowship or academic experience preferred. Body imaging/MRI or nuclear medicine with boards or ABR special competency strongly desired. Position includes all aspects of radiology. Practice is located in Boise, ID, which has many recreational and cultural amenities. Reply to Paul Traugher, M.D., or J. Tim Hall, M.D., Dept. of Radiology, St. Alphonsus Regional Medical Center, 1055 No. Curtis Rd., Boise, ID 83706; (208) 378-2161. 8-1ap

NUCLEAR MEDICINE / RADIOLOGIST, CALIFORNIA—Immediate opening for diagnostic radiologist with nuclear medicine boards or special competency in growing private practice in the San Fernando Valley 20 minutes north of UCLA. Candidate to supervise growth of nuclear medicine dept. in addition to general diagnostic radiology work. Full partnership tract with excellent salary. Practice includes hospital and imaging centers. Group consists of young enthusiastic radiologists all with fellowship training. Equipment includes Sopha Spect nuclear, GE 1.5-T MRI with angio, 2 Acuson ultrasound, Siemens Angiostar specials, and 2 Picker 1200 CT scanners. Send CV to T. Sprague M.D., Holy Cross Medical Center, 15031 Rinaldi St., Mission Hills, CA 91345; fax (818) 898-4451. 9-2ap

INTERVENTIONAL NEURORADIOLOGIST, COASTAL VIRGINIA—A 32-physician private radiology group which practices in 6 hospitals and several offices is seeking an interventional neuroradiologist who is eligible for senior membership in the American Society of Neuroradiology. The individual's clinical responsibilities would be primarily limited to a 644-bed tertiary-care center with level 1 trauma status. Diagnostic equipment includes 2 state-of-the-art Signa 1.5-T GE MR scanners (4.79 software and angio package), a DFP 60A bi-plane bi-digital 1024 matrix Toshiba DSA system (with digital stereo capabilities), and a Siemens DRH as well as a GE 9800 CT scanner. Some time would be spent at a 250-bed hospital with a Hitachi MRP-5000 0.2-T MR unit and a GE 9800 CT scanner with Hi-Light advantage software. Two (2) year fellowship trained neuroradiologists are already on staff. The practice is affiliated with a medical school and residency program which allows the pursuit of academic interests. The practice is located in a coastal resort area with a temperate climate and all water sports available. Interested persons should send a CV or contact Carl V. Bundschuh, M.D., Director of Neuroradiology and MRI, Medical Center Radiologists, Inc., 6161 Kempville Circle, Ste. 330, Norfolk, VA 23502; (804) 466-0089. 12xa

MAMMOGRAPHER—Large private multi-hospital group in a coastal city of Virginia seeks a radiologist with special interests in all aspects of mammography. The practice includes a tertiary-care hospital which is affiliated with both a medical school and a radiology residency training program, thereby offering the benefits of both private practice and academics. The position would include directorship of future mammography clinics. Additional aptitude in other aspects of diagnostic radiology with specialized and/or fellowship training preferred. Interested applicants please send CV or inquiries to Medical Center Radiologists, Halifax Building, Ste. 330, 6161 Kempsville Circle, Norfolk, VA 23502; (804) 466-0089. 12xa

INTERVENTIONAL RADIOLOGIST—An opportunity exists for an interventionalist to join a group of 12 board-certified radiologists in their hospital and private practice. Position requires fellowship-trained interventionalist with an interest in diagnostic radiology. The practice is based in a 430-bed community hospital with 2 private offices and a hospital owned satellite facility. Services include 2 MRI units, 2 CT units, 2 SPECT cameras, and a new interventional suite with an established interventional practice. Bethlehem is 1 of 3 cities situated in the Lehigh Valley which is within close proximity of NY and Philadelphia. Contact G. Edward Streubert, M.D., Bethlehem Radiologists Associates, 95 Highland Ave., Ste. 105, Bethlehem, PA 18017. 4-12ap

MINNESOTA—A 34-member multi-specialty group is seeking a BE/BC radiologist to join our expanding physician base. We offer an excellent first year guarantee, vacation, CME time, full health/dental, board study time, money purchase pension/profit sharing trust plans, and more. Beautiful lakes, unspoiled environment and 4 season recreation await you in Virginia, MN. For more information and a video call (800) 377-3290. 10-12ap

DIAGNOSTIC RADIOLOGIST, NEW MILFORD, CT—A third radiologist is sought for a busy, private practice located in one of the most beautiful areas of Connecticut. We provide the full range of diagnostic services for a modern, well-equipped, community hospital. Choice environment; excellent compensation. Send inquiries and CV to Jules White, M.D., New Milford Hospital, 21 Elm St., New Milford, CT 06776; (203) 355-2611, ext. 235. 10-1a

ULTRASOUND/CT/MRI—Opportunity for board-certified radiologist specializing in ultrasound, body CT, and body MRI to pursue academic career at the New York Hospital-Cornell Medical Center. Dept. provides state-of-the-art equipment, including Acuson and ATL ultrasound, GE 9800 CT, and GE Signa 1.5-T MR. Wide variety of ultrasound examinations include abdominal, OB/GYN, color Doppler, small parts, neonatal head, transvaginal, and transrectal. Prefer candidate with prior fellowship in sectional imaging or ultrasound. Responsibilities include clinical practice, teaching, and research. Position available 7-1-93. Please send CV to Elias Kazam, M.D., Dept. of Radiology, New York Hospital-Cornell Medical Center, 525 E. 68th St., New York, NY 10021. 10-1a

PART-TIME PEDIATRIC/GENERAL RADIOLOGIST, CENTRAL MASSACHUSETTS—Radiologist sought with special competence in pediatric radiology to join an 11-member group. We serve a 550-bed medical center that includes the regional 40-bed neonatal intensive care unit. Position involves sharing general responsibilities including CT, ultrasound, and mammography. Part-time position may become full-time. Please send CV to Richard Danford, M.D., Worcester Radiologists, 121 Lincoln St., Worcester, MA 01605; (508) 753-8151. 10-12a

EXCITING RADIOLOGIST OPPORTUNITIES NATIONWIDE!—Now is the time to make your move! ABSOLUTELY NO COST TO YOU. We specialize in RADIOLOGY only, so we understand your needs. Positions from Sunbelt to Northern-most regions. Both salaried and private practice opportunities with top money offered. Utilizing the Snelling Search Computer Network. We know of the positions first and give you the inside tracks! Fax your CV to (214) 258-1092, or mail to Snelling Search Medical Group, 1303 Walnut Hill Lane, Ste. 103, Irving, TX 75038. For information on specific positions call toll free (800) 259-5973. Ask for Roman. 12xa

DIAGNOSTIC RADIOLOGIST, COASTAL DOWNEAST MAINE—We'd rather pay recruiting fee to you than to agency. Call for details. Opening for BC/BE radiologist at progressive small rural hospital; college community. Solid financial opportunity. Will tailor arrangements to fit candidate's desire. Contact administration, Down East Community Hospital, Machias, ME 04654; (207) 255-3356. 9-12ap

DIAGNOSTIC RADIOLOGIST WITH FELLOWSHIP TRAINING OR SPECIAL INTEREST/ TRAINING—We are seeking board-certified individuals to add depth in certain areas of our practice. If you are currently looking for a change in employment, or if you will complete a fellowship or a residency with special interest/training in 1993 or 1994 in any of the following areas, please contact us, vascular interventional, musculoskeletal, ultrasound, neuroradiology. The group is based in Bloomington, Indiana, a beautiful big 10 university community of 50,000+ population, 1 hr from major metro area. Ten diagnostic radiologists servicing 2 hospitals, 1 outpatient center and other sites. Primary hospital has state-of-the-art equipment including 1.5-T MR. Send CV to, or contact, Phil Russell, P.O. Box 4366, Bloomington, IN 47402-4366; (812) 334-8948. 10-12ap

FACULTY POSITION IN ABDOMINAL IMAGING—Opportunity for board-certified radiologist specializing in abdominal imaging with emphasis on gastrointestinal studies, sonography, and abdominal CT and MR to pursue an academic career at the New York Hospital-Cornell Medical Center. The dept. provides state-of-the-art equipment, including fluoroscopy Acuson and ATL ultrasound, GE 9800 CT, and GE Signa 1.5-T MR. Wide variety of abdominal examinations are done. Prefer candidate with prior fellowship in sectional imaging CT, MR, or ultrasound. Responsibilities include clinical practice, teaching, and research. Position is available July 1, 1992. Send CV to Claudia Henschke, Ph.D., M.D., Director, Starr 9 Division (GI, GU, Chest), Dept. of Radiology, The New York Hospital-Cornell Medical Center 525 E. 68th St., New York, NY 10021. 11-1a

THE LOUISIANA STATE UNIVERSITY MEDICAL CENTER is actively seeking candidates for ultrasound/CT/MRI, bone, chest, nuclear medicine, GI, GU, neuroradiology, angiography/interventional, emergency room, pediatrics and mammography. We are expanding our dept. significantly and are looking for enthusiastic individuals who want to develop a more expansive clinical practice, teaching program and research activities. A perfect opportunity to shape your own section. Applicants must be BE/BC and qualify for licensure in Louisiana. Salaries are competitive nationwide. The university is developing areas of special interest, including a multidisciplinary center for study of neurosciences and plans are underway to purchase all new state-of-the-art equipment. Enjoy the cultural and jazz music of New Orleans. The beaches of Northern Florida are only 3 1/2 hrs away. LSUMC is an AA/EOE. Send CV and 3 references to Jane Clayton, M.D., Acting Chairman, Dept. of Radiology, LSUMC, 1542 Tulane Ave., New Orleans, LA 70112; (504) 568-4647, fax (504) 568-8955. 10-1a

INTERVENTIONAL RADIOLOGIST—Private multispecialty group of 125 physicians with university affiliation in Upper Midwest seeks second board-certified interventional radiologist. Excellent digital angiographic, CT and MR facilities. Superb cooperation with surgical staff. At least 50% interventional with option of some general and/or neuroradiology. Salary equals 90% of partners with full partnership in 1-2 yrs. City of 60,000 population with referral base of 300,000. Send CV to Gerald Smyser, M.D., The United Hospital, Box 6002, Grand Forks, ND 58206-6002; (800) 437-5375. 10-12ap

NEURORADIOLOGIST—A 25-person radiologic group in central New Jersey seeks a fourth neuroradiologist well-versed in all neuroimaging modalities and procedures. Senior member status eligibility in the ASNR is required. Practice includes 2,450-bed hospital, 3 offices, 3 MRI scanners, 5 CT scanners, a radiology residency, and medical student teaching. Send CV to Richard Feinstein, M.D., c/o Kathy McGrath, Radiology Group of New Brunswick, 230 Old Bridge Turnpike, South River, NJ 08882. 10-3a

IMMEDIATE OPENING for full-time or part-time board-certified/eligible radiologist(s) to join an established 4-man radiology group in the Pacific Northwest. All modalities including MRI. Attractive salary/benefits; partnership opportunity. Community offers quality lifestyle and yr-round recreational opportunities. Send CV to Lynn Ball, Tri-City Radiology, 969 Stevens Dr., Ste. 1-B, Richland, WA 99352. 11-1a

GENERAL RADIOLOGY—Board-certified radiologist with mammographic experience for outpatient facility at the New York Hospital-Cornell University Medical College. The dept. provides 2 state-of-the-art (GE-CGR) mammographic units, an Acuson ultrasound, modern fluoroscopic and radiographic multi-room facility and access to GE Signa 1.5-T MR. Responsibilities include clinical practice, resident and medical student teaching and academic programs. Facility is accredited by ACR in mammography. Qualification for ACR mammographic certification required. Please send CV to Michael D. F. Deck, M.D., Acting Chairman, Dept. of Radiology, The New York Hospital-Cornell University Medical Center, 525 E. 68th St., New York, NY 10021 AA/EOE 11-1a

NEURORADIOLOGY, ASST/ASSOC. PROFESSOR—Board-certified neuro-radiologist interested in academic practice with strong clinical and medical student and resident teaching orientation at the New York Hospital-Cornell University Medical College. The dept. provides state-of-the-art equipment with basic research opportunities available through Cornell University Medical College and close affiliation with Memorial Sloan Kettering Cancer Hospital and Rockefeller University. Senior membership of the American Society of Neuroradiology required. Please send CV to Robert Zimmerman, M.D., Dept. of Radiology, New York Hospital-Cornell University Medical Center, 525 E. 68th St., New York, NY 10021; (212) 746-2574, fax (212) 746-8597. AA/EO. 11-1a

STATE COLLEGE, PA—Two positions available in private billing, hospital-based group. Mammoradiologist, BC/BE preferable with fellowship to run ACR accredited breast center. Will replace retiring mammoradiologist currently performing 6,400 exams/yr. Liberal salary and benefits. No call or weekends. General diagnostic radiologist BC/BE, competent in all modalities. Salary and benefit package well above average. Modern, well-equipped hospital including new G.E. 1.5-T Signa Advantage MRI. We offer excellent quality of life in a beautiful central PA college town, home of Penn State U. Send CV to R.A. Rockower, M.D., Dept. of Radiology, Centre Community Hospital, 1800 E. Park Ave., State College, PA 16803 or call (814) 234-6137. 11-1ap

CHIEF—INTERVENTIONAL NEURORADIOLOGIST—University of Southern California Dept. of Radiology seeks an experienced interventional neuroradiologist to develop an ambitious program providing expertise for our new University Hospital, the LAC + USC Medical Center, the Childrens Hospital of Los Angeles, and the Norris Cancer Center. An individual with a large repertoire of diverse procedures is preferable since there is an excellent opportunity to develop an extremely large and versatile clinical services. Additional requirements include board-certification in radiology and a California state medical licensure. Interested parties are encouraged to contact Hervey D. Segall, M.D., Chairman, Neurointerventional Search Committee, USC Medical Center, Box 762, 1200 North State St., Los Angeles, CA 90033; (213) 226-7425 or (213) 681-9019. 11-12a

BODY IMAGING—University of Southern California Dept. of Radiology has an opening at assistant professor level for a radiologist with an interest in body imaging. Clinical activity sites include the Los Angeles County/USC Medical Center, a 1,500-bed public hospital, Kenneth Norris Jr. Cancer Hospital and Research Institute, a 60-bed national cancer institute designated comprehensive cancer center and the new USC University Hospital, a 275-bed private facility. Experience or fellowship in body imaging is expected. Board-certification by ABR and eligibility for California licensure is mandatory. Interested applicants should submit CV to Philip W. Ralls, M.D., Chief of Body Imaging and Interventional Radiology, LAC/USC County Hospital, Box 631, 1200 North State St., Los Angeles, CA 90033; (213) 226-7207. University of Southern California is an equal opportunity/affirmative action employer. 11-12a

DIAGNOSTIC RADIOLOGIST, HOUSTON, TX—18-member private practice group seeks BC individual with musculoskeletal or body imaging fellowship. State-of-the-art practice in 1,500-bed teaching hospital with 4 MRI, 5 CT, 7 ultrasound units. Contact P.C. Smith M.D., The Methodist Hospital, 6550 Fannin (ms d-281), Houston, TX 77030. 11-4xa

ULTRASOUND/MAMMOGRAPHY RADIOLOGIST, MINNEAPOLIS—Our 23-person radiology group seeks a BC/BE radiologist with fellowship training in ultrasound and mammography imaging for July 1, 1993. Our practice includes 2 large hospitals and 1 smaller community hospital, and 2 offices with mammography, all financially successful. All imaging modalities except PET available at each hospital. Our practice will soon begin breast biopsies with stereotactic mammography. Send CV and references including 1 from section chief to Eric L. Bressler, M.D., Suburban Radiologic Consultants, Ltd., 4801 W 81st St., Minneapolis, MN 55437. Inquiries during business hrs, (612) 337-4250. 11-12a

BODY IMAGING RADIOLOGIST, MINNEAPOLIS—Our 23-man radiology group seeks a BC/BE radiologist with fellowship training in body imaging for July 1, 1993. Our practice includes 2 large hospitals and 1 smaller community hospital, all financially successful. All imaging modalities except PET available at each hospital. Candidate would do about 50% body imaging and 50% general radiology. Send CV and references including 1 from Section Chief to Eric L. Bressler, M.D., Suburban Radiologic Consultants, Ltd., 4801 W 81st St., Minneapolis, MN 55437. Inquiries during business hrs, (612) 337-4250. 11-12a

MUSCULOSKELETAL RADIOLOGIST, MINNEAPOLIS—Our 23-man radiology group seeks a BC/BE radiologist with fellowship training in musculoskeletal imaging for July 1, 1993. Our practice includes 2 large hospitals and 1 smaller community hospital, all financially successful. All imaging modalities except PET available at each hospital. Our practice is subspecialized in orthopedic radiology. Candidate would do about 50% orthopedic and 50% general radiology including body imaging. Send CV and references including 1 from section chief to Eric L. Bressler, M.D., Suburban Radiologic Consultants, Ltd., 4801 W 81st St., Minneapolis, MN 55137. Inquiries during business hrs, (612) 337-4250. 11-12a

TRAUMA RADIOLOGIST—The State University of New York Health Science Center at Brooklyn seeks to add a board-certified/eligible radiologist to join the Division of Traumatology at Kings County Hospital Center, a 1,300-bed tertiary facility/Level I Trauma Center with an international reputation in trauma services. The radiologist is an integral member of the trauma service of the dept. of surgery. Opportunities to join ongoing clinical investigations of the use of radiography, CT, angiography/interventional radiology, and ultrasound in the trauma patient are available. Academic rank and salary are commensurate with experience. CV should be addressed to Salvatore J. A. Scialfani, M.D., Dept. of Radiology, Kings County Hospital Center, 451 Clarkson Ave., Brooklyn, NY 11203. An EO/AA employer. 11-1ap

CARDIOVASCULAR AND INTERVENTIONAL RADIOLOGIST—The State University of New York Health Science Center at Brooklyn seeks a board-certified/eligible radiologist with fellowship training in interventional radiology for a faculty position. The institution is a 1,700-bed facility, including the Kings County and the State University Hospitals. The medical center performs approximately 2,000 diagnostic and interventional procedures including angioplasty, embolization, caval filters, gastrointestinal, genitourinary, and pulmonary interventions. When ongoing renovations are complete, there will be 5 new vascular digital rooms. Research time and facilities are available. Rank and salary are commensurate with qualifications. CV should be addressed to Salvatore J.A. Scialfani, M.D., Kings County Hospital Center, Dept. of Radiology, 451 Clarkson Ave., Brooklyn, NY 11203; (718) 245-4447. An EO/AA. 11-1ap

MRI/CT/ULTRASOUND—The State University of New York/Health Science Center at Brooklyn seeks a board-certified/eligible physician to join the faculty in cross-sectional imaging. The medical center is a 1,700-bed facility including Kings County Hospital and the State University Hospital. The medical center performs over 250,000 diagnostic procedures/yr. Currently 4 state-of-the-art CT scanners with a fifth to be installed shortly. A GE Signa was recently installed and a second is planned. Seventeen ultrasound units are in clinical use. Research time and facilities are available. The 2 hospitals are connected with a PACS System via a microwave link. Rank and salary are commensurate with qualifications. CV should be addressed to Joshua A. Becker, M.D., Professor and Chairman, Dept. of Radiology, SUNY/Health Science Center at Brooklyn, 450 Clarkson Ave., Brooklyn, NY 11203. Equal opportunity employer 11-1ap

LOUISIANA—Diagnostic radiologist needed in busy practice including all modalities including vascular and MRI. Excellent benefits, salary, and early partnership. Partner retiring. University community of 100,000 with abundant outdoor recreation. CV to Dan Davidson, M.D., 3000 W. Deborah Dr., Monroe, LA 71201; (318) 388-7810. 11-1a

DIAGNOSTIC RADIOLOGIST, NORTHEAST MICHIGAN—Excellent practice opportunity available for a diagnostic radiologist to commence in the autumn of 1992. Alpena Radiology, P.C., seeks a BC/BE radiologist to complete our 3-man group. We offer excellent income, early partnership and idyllic lifestyle. We require a friendly, hard-working individual who will be a team player. The ability to work well with us and our excellent medical staff is a must. Alpena General Hospital is a modern 175-bed facility located on the shores of Lake Huron. The hospital provides all radiology equipment including: new R&F equipment (G.E.), Siemens CT, SPECT nuclear imaging, color flow Doppler, DSA, ACR accredited mammography. Siemens mobile MRI will commence shortly. The hospital administration is very supportive. The Alpena area is a sportsman's paradise. Sailing, boating, golf, fishing, hunting, skiing, etc. are all minutes away. Our moderate winters and Mediterranean summers are ideal. For more information please contact Steven Zweig, M.D. or James Weeks, M.D., Dept. of Radiology, Alpena General Hospital, 1501 W. Chisholm St., Alpena, MI 49707; (517) 356-7250. 11-1a

FLORIDA, STAFF RADIOLOGIST—Opportunity for board-certified/eligible diagnostic radiologist with experience in reading plain films, fluoroscopy, ultrasound, CT, nuclear medicine, and some angiography in radiology service at this GM&S Dept. of Veterans Affairs (VA) Medical Center. Affiliation in surgery with the University of Florida. Excellent employment benefits including 30 days paid vacation and 15 paid days sick leave per yr; liberal life and health insurance benefits; malpractice insurance; and retirement program. Moving expenses paid. Lake City, FL is located in northern Florida with a mild climate yr round. Extensive outdoor recreational activities. Reasonable cost of living, no state income tax, fine schools, local community college, and nearby universities which provide opportunities for continuing education and cultural diversion. Licensure in any state acceptable. Contact or send CV to Richard Parker, M.D., Chief of Radiology, VA Medical Center, Lake City, FL 32055-5898; (904) 755-3016 ext. 2543. An equal opportunity employer. 11-5a

RADIOLOGIST NEEDED—Thomaston, GA approximately 60 miles south of Atlanta, GA. Because of future retirement of a senior partner we are looking for a board-certified or eligible partner around June or July 1993. Interested in someone with special interest in imaging (CT & MRI) but at the same time comfortable with angiography and general radiology. Excellent salary and fringe benefits. Contact Ken Morgan, M.D., (706) 647-9745 or 647-1431; Fax (706) 647-9370. 11-2a

DIAGNOSTIC RADIOLOGIST—Large private multi-hospital group in a coastal resort area of Virginia is seeking a BC/BE general diagnostic radiologist with proficiency in mammography, ultrasound, CT and general diagnostic radiology. MRI proficiency would also be helpful. The practice includes 5 large hospitals, 2 private offices and several outpatient imaging sites. The practice is also affiliated with a medical school and supports a residency program with 14 residents, thereby offering the benefits of both private practice and the pursuit of academic interests. Fellowship training preferred. Interested applicants should send their CV to Medical Center Radiologists, Inc., Halifax Bldg., Ste. 330, 6161 Kempsville Circle, Norfolk, VA 23502; (804) 466-0089 for further information. 12xa

PACIFIC NORTHWEST—Opportunity for BC/BE general diagnostic radiologists to join group of 5 board-certified radiologists. Experience in all modalities desired. Practice includes 2 hospitals and private office in Southern Oregon. Competitive starting salary with early full partnership. Excellent lifestyle with abundant recreational activities from Pacific Coast to Oregon Cascades. Practice in a family-oriented community with natural beauty. Send CV to Larry Strickland, Administrator, Roseburg Radiologists, P.C., P.O. Box 1547, Roseburg, OR 97470; (503) 673-4303.

MRI/NEURORADIOLOGY/FLORIDA—Private MRI center seeks board-certified radiologist with MRI experience to oversee and direct diagnostic center. Excellent salary, complete benefit package and excellent recreational activities in growing Ft. Lauderdale community. Reply to Michael Abrahams, M.D., 6971 W. Sunrise Blvd., Plantation, FL 33317; (305) 792-1110. 11-1a

WATERFRONT, SOUTHERN MICHIGAN—X-ray Associates of Port Huron, MI, is seeking a seventh BC/BE diagnostic radiologist. Our 3 hospital-based practice features nuclear medicine, CT, ultrasound, Doppler, accredited mammography, and general radiography at all sites. Two sites also feature modern cardiovascular suites. A tri-hospital MRI center is featured at the largest site. Interventional skills are desirable but not mandatory. A hardworking, congenial, adaptable individual is an ideal candidate for our team-oriented radiology practice. Salary commensurate with experience, usual benefits, partnership in 2 yrs. Our Canadian-border community of 40,000 has seen rapid commercial growth in spite of the nation-wide recession. We have a small town atmosphere, good local school system, all water related outdoor activities, and most small city amenities. Please send CV to Clare A. Scheurer, M.D., 1002 Tenth Ave., Port Huron, MI 48060. For more information call (313) 987-1237, evenings. 11-4a

CHEST RADIOLOGIST—Large private multi-hospital group in a coastal resort area of Virginia is seeking a BC/BE general diagnostic radiologist with expertise in pulmonary radiology. The practice includes 5 large hospitals, 2 private offices and several outpatient imaging sites. The practice is also affiliated with a medical school and supports a residency program with 14 residents, thereby offering the benefits of both private practice and the pursuit of academic interests. Fellowship training preferred. Interested applicants should please send their CV to Medical Center Radiologists, Inc., Halifax Bldg., Ste.330, 6161 Kempsville Circle, Norfolk, VA 23502; (804) 466-0089 for further information. 12xa

RADIOLOGIST TO HEAD WOMEN'S CLINIC, WITH SPECIAL EXPERTISE IN MAMMOGRAPHY AND ULTRASOUND—A regional women's clinic for mammography, breast ultrasound, and mammographically controlled needle aspirations and biopsies will open soon at John L. McClellan Veteran's Medical Center in Little Rock, AR. A radiologist to head this section is urgently needed. That individual will be assigned to certain general radiology duties part-time until a similar clinic opens at the University of Arkansas for Medical Sciences, at which time supervision of both women's centers will presumably be a full-time position. Applications should be submitted to University of Arkansas for Medical Sciences, Ernest J. Ferris, M.D., Professor and Chairman, Dept. of Radiology, Slot 556, 4301 W. Markham St., Little Rock, AR 72205; (501) 686-5740. 12-2a

THE CREIGHTON UNIVERSITY SCHOOL OF MEDICINE, OMAHA, NE, has instituted a search to fill the position of Chair of the Dept. of Radiology. Significant research accomplishments and publications, demonstrated clinical skills, and commitment to teaching at both the student and resident level are the characteristics which will be most valued by the search committee. The dept. includes a nationally recognized PET Center with emphasis on both basic research and clinical applications. Nominations are welcome. Applicants should submit a CV to Michael H. McGuire, M.D., Professor and Chairman, Dept. of Surgery, Radiology Search Committee Chair, Creighton University School of Medicine, 601 N. 30th St., Omaha, NE 68131. Creighton University is an equal opportunity employer. 12a

DIAGNOSTIC RADIOLOGIST—Mallinckrodt Institute of Radiology, Washington University, seeks an additional board-certified radiologist with academic interest to join 2 radiologists at a satellite hospital of Barnes Hospital in St. Louis. This satellite radiology facility in St. Louis County performs all aspects of diagnostic radiology, including CT, MRI, ultrasound, and nuclear medicine. Equipment is brand new and state-of-the-art. Candidates must be competent in all aspects of diagnostic radiology and must be able to do cross-sectional interventional procedures. Academic rank and salary are dependent on qualifications and previous experience. The Institute is conducting research in teleradiology and outcomes research at the satellite facility. Washington University is an equal opportunity employer, applications from women and minority group members are encouraged. Send CV to R. Gilbert Jost, M.D., Chief of Diagnosis, Mallinckrodt Institute of Radiology, 510 S. Kingshighway Blvd., St. Louis, MO 63110. 11-1ap

MAMMOGRAPHY/RESEARCH, UNIVERSITY OF PENNSYLVANIA—Half-time position in mammography or full-time position combining clinical mammography and a partially grant-funded research program in image perception and transmission with Dr. Harold Kundel. High volume, rapidly expanding clinical section with ongoing problem solving mammography, breast ultrasound and needle localizations. Opportunities for additional collaborative projects with radiation oncology, MRI and surgery. Resident and student teaching responsibilities as well as participation in outpatient bone and chest radiology. Position available immediately. Applicant must be ABR certified and able to obtain license in Pennsylvania. University of Pennsylvania is an affirmative action, equal opportunity employer and specifically encourages applications from women and minorities. Send letter and CV to Rosalind H. Troupin, M.D., Dept. of Radiology, Hospital of the University of Pennsylvania, 3400 Spruce St., Philadelphia, PA 19104. 12-2a

VASCULAR AND INTERVENTIONAL RADIOLOGIST—The University of Arkansas for Medical Sciences is seeking a faculty member for our vascular and interventional radiology section. Candidates should be board-certified and fellowship-trained, and interested in a combined clinical, teaching and research environment. Clinical duties include coverage of a university hospital, a large veteran's hospital and a children's hospital. Active vascular and non-vascular research programs are in place. Salary and fringe benefits are competitive. Applications should include a current CV. For further information, please contact either David R. McFarland, M.D., Chief, Section of Vascular and Interventional Radiology, Steven K. Teplick, M.D., Professor and Vice Chairman, or Ernest J. Ferris, M.D., Professor and Chairman, Dept. of Radiology/556, University of Arkansas for Medical Sciences, 4301 W. Markham, Little Rock, AR 72205; (501) 686-6910. 12-2a

MAINE—BC/BE diagnostic radiologist with interventional skills. Join well-established multidimensional group. Associate leading to partnership. Competitive financial package. Family-oriented small city. Business and cultural center. Major university. One hr to coast. Easy access to ski areas. Send CV to New England Health Search, 63 Forest Ave., Orono, ME 04473; (207) 866-5680. 12-2ap

MUSCULOSKELETAL RADIOLOGIST, CHARLOTTE, NC—A 13-member, subspecialized group serving a 660-bed, private community hospital, outpatient diagnostic center desires a fellowship-trained or staff level musculoskeletal radiologist. GE 9800 CT and Signa 1.5-T equipment. Family-oriented community with warm 4-season climate, centrally located between coast and mountains. Send CV to P. O. Box 221211, Charlotte, NC 28222. 12-2a

RADIOLOGIST—Eight-person group seeks general radiologist with fellowship training and special interest in MRI for 92-bed hospital and several imaging centers. Practice in the rapidly growing north San Diego and Temecula Valley areas. Send CV to North Coast Imaging Radiology Medical Group, Inc., 1582 W. San Marcos Blvd., Ste. 104, San Marcos, CA 92069; (619) 744-6442.

GENERAL RADIOLOGIST WITH ANGIO/INTERVENTIONAL SKILLS—The Dept. of Radiology at Graduate Hospital is looking for a general radiologist with a subspecialty interest in vascular/interventional radiology. Other special interests or experience welcome. The successful applicant will join a 13-person radiology group in a tertiary-care hospital in Center City, Philadelphia, affiliated with the University of Pennsylvania. A new, state-of-the-art angiography suite has just been installed. Inquiries and CVs should be addressed to Jerome G. Jacobstein, M.D., Chairman, Dept. of Radiology, Graduate Hospital, One Graduate Plaza, Philadelphia, PA 19146; (215) 893-2041. 12-2a

MRI RADIOLOGIST WANTED for private MRI facility in beautiful, safe area in New York, close to beaches, 50 min. from New York City. Experience in MRI interpretation required. New graduates with MRI fellowship/background welcome. Send CV to AJR Box reply # 12 (see address this section) 12-1a

BC/BE RADIOLOGIST to join VA Medical Center in Martinsburg, WV, a 316-bed hospital, 150-bed nursing home and 520-bed domiciliary located 75 miles from Washington, DC, or Baltimore, MD, in the Shenandoah Valley. Comprehensive benefit package. EOE. Contact J. Henderson, Office of COS, VAMC, Martinsburg, WV 25401; (304) 263-0811 ext. 4015. 12-2a

GOOD LIFE, GOOD MONEY—Radiologist needed for growing practice that covers 2 hospitals as well as 2 free-standing clinics. Modalities include R&F, general, mammography, CT, MRI, nuclear medicine, SPECT, and special procedures. Denton, population 60,000, located 30 mi. north of Dallas/Fort Worth, has 2 recreational lakes within 15 mi. and 2 major universities. Attractive financial and benefit packages are offered. Contact Family Radiology with CV at 1614 Scripture, Ste. 2, Denton, TX 76201; (817) 387-6159. 12a

PRACTICE OPPORTUNITY IN FAST GROWING LAS VEGAS, NV—Expanding 9-member radiology group is seeking 2 additional BE/BC radiologists for July 1993. We currently serve 2 hospitals and 1 outpatient center with 2 additional outpatient centers scheduled to open within the yr. Outstanding salary and benefits package leading to full partnership in 2 yrs. Send CV or contact Marc Pomerantz M.D., Head of Search Committee, 1925 Spode Ave., Henderson, NV 89014; (702) 458-3191. 12-5ap

RESIDENTS—Due to a recently approved expansion of the program, the University of Michigan is seeking to recruit radiology residents for July 1993 at the second yr level. This fully accredited program provides training in all imaging modalities at the University of Michigan Hospitals and affiliated Veterans Administration Medical Center. Applicants must be eligible for Michigan licensure. Please forward your CV and letter of interest to N. Reed Dunnick, M.D., Professor and Chair, Dept. of Radiology, University of Michigan Hospitals, 1500 E. Medical Center Dr., Ann Arbor, MI 48109-0030. A nondiscriminatory, affirmative action employer. 12-1a

SEATTLE-AREA/TWO POSITIONS—Ten-person group seeks radiologist with fellowship training in ultrasound and body imaging for 200-bed hospital and outpatient imaging center. Established practice in Bellevue area. Applicant must be board-certified and licensed in Washington state. Competitive salaries and excellent benefits offered. Address inquiries and current CV to Eastside Radiology, Dr. Allen, P.O. Box 806, Bellevue, WA 98009. Dedicated mammography for outpatient practice requires fellowship-trained or equivalent experience, board-certified and licensed in Washington state. Send inquiries to above address, Dr. Philip Lowe. 12-1a

DIRECTOR, NEURORADIOLOGY SERVICE—The Dept. of Radiology at the 1,400-bed Columbia-Presbyterian Medical Center in New York City is searching for a qualified director of neuroradiology. We are seeking a director who will participate in and organize the daily clinical work, supervise residents and fellows, foster and further develop the traditional excellence of our research programs and administer the service. Equipment available to the clinical service, which is moving to space in our new hospital building, includes 3 new 1.5-T MRI units (shared), 2 GE 9800 CTs, 2 new bi-plane digital angio units (1 on order, 1 operational) and a bi-plane myelography room. The new unit is adjacent to the neurosurgery ORs and the neuro/neurosurgery ICU, and is part of the main radiology dept. The staff currently consists of 5 attending neuroradiologists and 4 fellows. In addition, there is an active, well-staffed interventional neuroradiology service. Several funded grants exist in the division including a multi-yr program project on high-field MRI, which is an ongoing focus of our research efforts. Salary and academic rank will be commensurate with experience and qualifications. Board-certification in diagnostic radiology and a NYS medical license required; narcotics license desirable. Please send resume to Philip O. Alderson, M.D., Professor and Chairman, Dept. of Radiology, 177 Fort Washington Ave., New York, NY 10032. Columbia University is an affirmative action/equal opportunity employer. 12a

PEDIATRIC RADIOLOGIST—Nine-person group in Austin, TX, seeks a fellowship-trained pediatric radiologist to practice in a 363-bed community hospital, a 75-bed children's hospital and an outpatient imaging center. The children's hospital is scheduled to expand by 120 beds in the next 2 yrs. Address inquiries and CV to Radiology Consultants, 711 W. 38th St., Austin, TX 78705. Attention Jack Boyd, M.D.; (512) 454-8718. 12a

RADIOLOGIST—The Dept. of Radiology of the Henry M. Jackson Foundation, a non-profit research and education foundation, is seeking a radiologist with expertise in general radiology, ultrasound, body CT, and MRI to join its 14-member faculty. The dept. of radiology is located within the Warren G. Magnuson Clinical Center at the National Institutes of Health (NIH). This position offers a stimulating academic environment in the world's largest research hospital as well as proximity to the many cultural benefits of Washington, DC. The NIH has 3 clinical and 4 research MRI units, 4 CT units, 3 color Doppler ultrasound units, and 2 angiography suites. The NIH environment provides the interested individual ample opportunity to pursue collaborative clinical and basic research as well as other academic activities. Workloads and call schedules are very reasonable. The position is non-federal; salary and benefits are competitive with other academic centers. If you are looking for a pleasant and stimulating practice, send a CV to John L. Doppman, M.D., Chairman, Building 10, Rm 1C660, NIH Bethesda, MD 20892. The Henry M. Jackson Foundation offers an excellent benefits package and is an equal opportunity employer. 12ap

UCSD SCHOOL OF MEDICINE—The Dept. of Radiology is seeking a radiologist with special expertise in all aspects of Doppler/vascular ultrasound to direct the ultrasound vascular laboratory. Participation in other diagnostic subspecialties is available. Qualifications required: Board-eligibility/certification; California medical license; and 1-yr fellowship in ultrasound. Title Series: Assistant/associate/full professor (in-residence or clinical series - not currently a tenure-track position); level based on yrs experience; salary commensurate with rank and step of appointment based on the established salary schedule of the UCSD School of Medicine Faculty Compensation Plan. The University of California, San Diego, is an equal opportunity/affirmative action employer. All CVs received prior to January 1, 1993, or thereafter until position is filled will be given full consideration. Send to Barbara B. Gosink, M.D., Professor of Radiology, Dept. of Radiology, 8759, UCSD Medical Center, 200 West Arbor Dr., San Diego, CA 92103. 12a

INTERVENTIONAL RADIOLOGIST—Large radiology group with a 2-hospital-based practice and multiple private offices seeks a board-certified interventional radiologist interested in a full-time position. Training in CT, ultrasound, MRI and/or nuclear medicine is also preferred. Your interventional/angiography responsibilities would amount to approximately 30% of your time. Excellent southern New Jersey location. Competitive salary and benefit package. Send CV to RABC, P.O. Box 729, Mt. Holly, NJ 08060. 12-3a

RADIOLOGIST—Full-time BC/BE, VA Medical Center, 165-bed GM & S. Excellent GE equipment, duplex Doppler, ultrasound, diagnostic and fluoroscopic, CT interpretation, state university city and hills and lakes in NW Arkansas, with cultural and recreational attractions. Competitive salary (approximately \$125,000), excellent benefits/retirement. No malpractice insurance needed. Basic 40 hr work week. Call Chief of Staff, (501) 444-5050. 12-2a

INTERVENTIONAL RADIOLOGIST, SOUTH JERSEY—Radiologist with fellowship training or equivalent experience in interventional radiology to join 5-member group with active hospital-based practice. State-of-the-art angiography equipment on-site. The hospital is affiliated with the University Medicine and Dentistry of New Jersey School of Osteopathic Medicine in Stratford, NJ. Position includes patient care and resident teaching. Excellent location 1/2 hr from Philadelphia and 1 hr from the Jersey Shore. Great lifestyle. Competitive salary and benefits. Send CV or call Beth K. Reichman, Corporate Director, Physician Relations, Kennedy Memorial Hospitals-UMC, 500 Marlboro Ave., Cherry Hill, NJ 08003; (609) 661-5149. 12-1a

DIAGNOSTIC RADIOLOGIST—Recent fellowship or faculty status preferred. Early partnership. We are a private practice group of 10 board-certified radiologists practicing general radiology with specialty interests accommodating all diagnostic and interventional modalities, including MRI. Our 350-bed hospital is a primary teaching affiliate of the University of Massachusetts Medical School with yr-round medical students and house-staff in several depts. The Berkshire Mountains are a desirable summer, winter and foliage resort community, less than 3 hrs drive to Boston, New York City, Vermont skiing and ocean. Quality of our practice, hospital and affiliates offices, and style of life are superior. Please respond with CV to Stuart J. Masters, M.D., Chairman, Dept. of Radiology, Berkshire Medical Center, 725 North St., Pittsfield, MA 01201. 12-2cp

RADIOLOGIST—East Hudson Radiologists, P.C., located in the greater region of upstate New York, is recruiting radiologists with fellowship(s) in cross-sectional, interventional, and/or neuroradiology. Our practice provides services to 6 hospitals, 4 practice-owned imaging centers, and numerous private offices and health related facilities. Candidates must be board-certified/eligible and meet American College of Radiology standards, as well as all facility credentialing. Please send CV to Shirish Parikh, M.D., President/CEO, East Hudson Radiologists, P.C., 451 Hoosick St., Troy, NY 12180.

IMMEDIATE OPENING—The Dept. of Radiology at the University of Massachusetts Medical Center has a full-time position available in the musculoskeletal division at a rank and salary commensurate with experience. The medical center is a 370-bed university hospital and medical school located approximately 40 miles west of Boston. The dept. consists of 25 staff, 15 residents, and 24 fellows and does approximately 140,000 exams/yr. The dept is well-equipped with 2 GE 9800 HiLite CT scanners as well as 2 GE 1.5-T MRI scanners and a 2.0-T small-bore unit for animal research in a stand-alone facility. The hospital is a level I trauma center maintaining a full-time trauma service and an active emergency room with an associated emergency medicine residency of approximately 36 residents. The hospital is serviced by a Life Flight helicopter. A strong interest in teaching and collaborative clinical research is desired. For further information contact Edward H. Smith, M.D. Professor and Chairman, Dept. of Radiology, University of Massachusetts Medical Center, 55 Lake Ave. North, Worcester, MA 01655; (508) 856-3253. UMMC is an equal opportunity/affirmative action employer. 12ap

CONNECTICUT, GENERAL DIAGNOSTIC RADIOLOGIST—Opening in July 1993 for BC/BE radiologist. Additional fellowship training may be a consideration in selection but is not a requirement. Nine-radiologist practice includes a 430-bed university affiliated, community hospital and a 60-physician multispecialty clinic. Approximately 110,000 exams/yr including MRI, CT, nuclear medicine, ultrasound and an active angiographic and interventional service. Excellent salary and benefits leading to full partnership. For more information, send CV to David A. Lund, M.D., Dept. of Radiology, New Britain General Hospital, 100 Grand St., New Britain, CT 06050. 12-3a

PENNSYLVANIA—Interested in a hospital-based group practice close to Manhattan and Philadelphia? The Dept. of Radiology at the Geisinger Wyoming Valley Medical Center seeks a diagnostic radiologist with special imaging skills to join 5 others in practice at their 230-bed medical center in the beautiful Poconos. Busy practice has excellent pathology; modern equipment includes MRI, CT, SPECT, and new digital angiogram. Call is shared equally. Compensation is competitive with private practice partnership; benefits include insurances, annuities, 4 weeks vacation and 4 weeks CME. The region boasts affordable housing, excellent schools (12 colleges) and a family-oriented lifestyle. For no-obligation packet, call Carole Gregory at (800) 220-6331 or CV to MedQuest, P.O. MQ, Devault, PA 19432. 12a

Position Desired

BOARD-CERTIFIED, PROGRESSIVE, TEAM ORIENTED, GENERAL RADIOLOGIST with 22 yrs in private practice seeks locum tenens or full or part-time permanent position in greater Houston, TX or the Austin, TX, area. Competent in general radiology, nuclear medicine, ultrasound, CT and MRI. One hundred to 150 hrs/yr CME. Recent 1-yr fellowship in MRI-neuro. Numerous references. CV and references upon request. Radiology 5322 West Bellfort, Ste 116, Houston, TX 77035-3035; office (713) 721-1880 or home (713) 342-4935. 12b

Fellowships and Residencies

FELLOWSHIP IN VASCULAR AND INTERVENTIONAL RADIOLOGY—The University of Arizona is sponsoring a 1-yr fellowship in vascular and interventional radiology beginning July 1, 1994. In-depth clinical experience and training in all aspects of interventional radiology will be offered. Facilities at the university hospital (300-bed) and Tucson Veterans Hospital (300-bed) are state-of-the-art. Interested applicants should submit a current CV and 3 letters of recommendation (including one from their program director) to Gerald D. Pond, M.D., Head, Section of Vascular and Interventional Radiology, University of Arizona Health Sciences Center, Tucson, AZ 85724. For further information please contact Ruth Kneup at (602) 626-6794. 12xc

FELLOWSHIP POSITION: WOMEN'S IMAGING—High-volume breast imaging (mammography, breast ultrasound, interventional procedures) and ultrasound with emphasis on obstetrical and gynecologic sonography. State-of-the-art mammographic and sonographic equipment including stereotactic table and digital capability. Using stereotactic, ultrasound, or mammographic guidance, all breast interventional procedures are performed, including fine needle and core biopsies, cyst aspirations, presurgical localizations, and galactography. Elective time in MRI, CT, and related clinical specialties (surgery, pathology, obstetrics-gynecology). One-year fellowship to start in July 1993. Fellows also have the opportunity to participate in teaching, conference presentations, and research projects, many of which culminate in publications. Inquiries should be addressed to Ellen B. Mendelson, M.D., Chief, Mammography and Women's Imaging, The Western Pennsylvania Hospital, 4800 Friendship Ave., Pittsburgh, PA 15224. 5-12c

FELLOWSHIPS AT THOMAS JEFFERSON UNIVERSITY HOSPITAL—The Dept. of Radiology at Thomas Jefferson University Hospital in Philadelphia offers the following fellowship programs each yr: (1) Ultrasound/CT/MRI—Jefferson's ultrasound division is one of the largest in the world and performs all currently available exams, including obstetric, vascular, lithotripsy, invasive, and endoluminal. We also operate 4 GE 1.5-T MRI units and 3 CT scanners. Contact Barry Goldberg, M.D. regarding this program. (2) Cardiovascular/interventional—This division is housed in a new suite containing Philips angio units with DSA and performs the full range of vascular and non-vascular interventional procedures. Contact Geoffrey Gardiner, Jr., M.D. (3) Neuro/ENT radiology—very active clinical services supply a wealth of material to this division, which is housed in a neurosciences imaging center containing all imaging modalities. Contact Carlos Gonzales, M.D. (4) Breast imaging—Jefferson's new breast-imaging center performs approximately 85 studies/day including ultrasound and needle localizations. Contact Stephen Feig, M.D. (5) Chest—includes biopsies and CT. Contact Robert Steiner, M.D. (6) MRI—a dedicated body MRI program including excellent research opportunities in addition to a large clinical case load. Contact Donald Mitchell, M.D. (7) Ultrasound—a dedicated ultrasound program. Contact Barry Goldberg, M.D. (8) Musculoskeletal—includes MRI of the musculoskeletal system. Contact David Karasick, M.D. All program directors listed above can be contacted at the Dept. of Radiology, Thomas Jefferson University Hospital, Philadelphia, PA 19107. Jefferson is an equal opportunity/affirmative action employer. 12xc

FELLOWSHIP POSITIONS—The Dept. of Radiology of the Brigham and Women's Hospital-Harvard Medical School has 1- or 2-yr fellowship positions in the following areas: (1) cardiovascular and interventional, (2) neuroradiology, (3) CT/ultrasound/MR/interventional, (4) oncoradiology, (5) chest, (6) bone, (7) nuclear medicine, and (8) computer science. For more information, please send CV specifying your area of interest to B. Leonard Holman, M.D., Chairman, Dept. of Radiology, Brigham and Women's Hospital, 75 Francis St., Boston, MA 02115. Harvard Medical School and Brigham and Women's Hospital are equal opportunity, affirmative action employers. 5-4c

FELLOWSHIP PROGRAM IN INTERVENTIONAL RADIOLOGY—The fellowship offered is a 1-yr training program in interventional radiology. A high volume of studies provides excellent experience for the fellowship training program. The 1-yr appointment is intensive, supervised, and allows for graded responsibility in performance and interpretation of studies including angioplasty, atherectomy, arterial and biliary stents, and all drainage procedures. The fellowship training involves performance of interventional procedures under sonographic and CT guidance as well as fluoroscopy. Inquiries should be addressed to Gordon K. McLean, M.D., Director, Interventional Radiology, The Western Pennsylvania Hospital, 4800 Friendship Ave., Pittsburgh, PA 15224. 5-12c

INTEGRATED CHEST RADIOLOGY FELLOWSHIP AT JOHNS HOPKINS UNIVERSITY HOSPITAL—The Dept. of Radiology, Division of Thoracic Imaging, Johns Hopkins University, is offering a 1- or 2-yr academically-oriented fellowship in chest radiology. The fellowship offers an integrated experience in cross-sectional imaging including over 4,000 chest CT exams/yr and 1,000 thoracic MRI examinations. Strong research interests in high-resolution computed tomography, magnetic resonance imaging, and interventional thoracic radiology offer the potential candidate an exciting environment to work in. The fellowship is available starting July 1, 1993, or July 1, 1994. Contact Janet E. Kuhlman, M.D., Director of Chest Radiology, Dept. of Radiology, Johns Hopkins Hospital, Baltimore, MD 21287; (410) 955-4419. 10-1c

FELLOWSHIP IN ULTRASOUND AND BODY CT/MRI—One-yr fellowships in ultrasound and body CT/MRI beginning July 1, 1993, and July 1, 1994, are being offered by the New York Hospital-Cornell Medical Center. The dept. provides state-of-the-art equipment, including Acuson and ATL ultrasound, GE 9800 CT, and GE Signa 1.5-T MR. Wide variety of ultrasound examinations include abdominal, OB/GYN, color Doppler, small parts, neonatal head, transvaginal, and transrectal. Applicants should be ABR eligible or certified. Send CV to Elias Kazam, M.D., Dept. of Radiology, New York Hospital-Cornell Medical Center, 525 E. 68th St., New York, NY 10021. 10-1c

IMAGING (ULTRASOUND, BODY CT, AND MRI) FELLOWSHIP TO BEGIN JULY 1993—The Dept. of Radiology at The Western Pennsylvania Hospital (a 578-bed advanced, tertiary-care teaching hospital), Pittsburgh, PA, offers a 1-yr imaging fellowship. The fellowship emphasizes diagnostic ultrasound with rotations in body magnetic resonance imaging and computed body tomography. Examinations in all areas of sonography are performed and include obstetrics and gynecology, vascular/Doppler, abdominal, prostate, pediatrics, breast, and small parts. State-of-the-art equipment in all areas of the dept. Fellows will participate in procedures guided by ultrasound and computed tomography. Fellows have ample opportunity to participate in conference presentations and research projects, many of which culminate in publications. Inquiries should be addressed to Marcela Bohm-Velez, M.D., Director of Imaging Fellowship Program, Dept. of Radiology, The Western Pennsylvania Hospital, 4800 Friendship Ave., Pittsburgh, PA 15224. 5-12c

ACCREDITED FELLOWSHIPS IN PEDIATRIC RADIOLOGY AND PEDIATRIC NEURORADIOLOGY—Dept. of Radiology, Children's Hospital Medical Center, Cincinnati, OH, offers 1- or 2-yr accredited (Residency Review Committee for Radiology of ACGME) fellowships in pediatric radiology beginning July 1, 1994. A 1-yr pediatric neuroradiology fellowship program is also offered and may be taken separately or combined with 1 yr of adult neuroradiology fellowship at the University of Cincinnati Medical Center. Children's Hospital Medical Center (CHMC) is a 355-bed institution. The dept. performs over 105,000 radiological exams/yr in the largest children's hospital and ambulatory practice in the U.S. The dept. has 14 full-time faculty pediatric radiologists, 1 full-time research faculty, 7 fellows, and many resident trainees. Six pediatric radiology and 1 pediatric neuroradiology fellowship positions are available annually. Training includes all aspects of pediatric imaging: neonatal radiology; neuroimaging; musculoskeletal radiology; cardiovascular and thoracic imaging; abdominal imaging; oncologic imaging; ultrasonography; nuclear medicine; computed tomography; MRI; and vascular/interventional procedures. The dept. has an active clinical service with state-of-the-art equipment as follows: digital fluoroscopy; Acuson and ATL ultrasound units with Doppler and color flow Doppler capabilities; planar SPECT gamma cameras; GE 9800 Quick CT scanner; 1.5-T GE MRI with spectroscopy, and cardiac catheterization/angiographic suite with digital vascular imaging. The fellowship provides a broad clinical experience in pediatric radiology as well as numerous opportunities to participate in both clinical and basic research. Candidates must be board-certified or board-qualified in diagnostic radiology and must obtain an Ohio medical license. Salary and fringe benefits are highly competitive. Applications are due prior to February 1993 with interviews scheduled during the fall and winter of 1992-93. There are numerous career opportunities in pediatric radiology and pediatric neuroradiology in both academic and private practice settings. To receive more information about the fellowships at CHMC or careers in pediatric radiology, please contact Director, Dept. of Radiology, Children's Hospital Medical Center, Cincinnati, OH 45229-2899; (513) 559-8058. Children's Hospital Medical Center and the University of Cincinnati College of Medicine are affirmative action/equal opportunity employers. 7-1c

ONCORADIOLOGY/MAMMOGRAPHY FELLOWSHIP—The Dept. of Radiology at the Dana-Farber Cancer Institute and Brigham and Women's Hospital, which are Harvard Medical School affiliates, offers a 1-yr fellowship position beginning July 1, 1993. All imaging modalities involved in the diagnosis, staging, and follow-up of patients with malignant disease are integrated into this program. An additional feature is a concentrated experience in the performance of interventional breast diagnostic procedures. Please contact Jack E. Meyer, M.D., Director of Diagnostic Radiology, Brigham and Women's Hospital and Dana-Farber Cancer Institute, 75 Francis St., Boston, MA 02115; (617) 732-6269. Brigham and Women's Hospital/Dana Farber Cancer Institute/Harvard Medical School is an affirmative action/equal opportunity educator and employer. 5-4c

CARDIAC IMAGING FELLOWSHIP (CLEVELAND CLINIC FOUNDATION)—The section of cardio-vascular imaging (division of radiology) announces to interested and qualified BC/BE radiologists a 2-yr cardiac imaging fellowship position (July 1, 1994 - June 30, 1996). This fellowship emphasizes integrated diagnostic imaging of acquired and congenital diseases of the heart and thoracic vasculature using non-invasive radiologic techniques (plain-film xray, CT, MRI, Nuclear Cardiology including PET) through a balance of practical clinical and research experiences. Research activities are complemented by lectures and technical assistance from the division's biostatistician. Didactic training both in cardiac catheterization/cine cardio-angiographic interpretation and in performance/interpretation of echocardiography is coordinated with the dept. of cardiology for clinical and research cross-correlation. Direct all correspondences to Richard D. White, M.D. Head, Section of Cardio-Vascular Imaging, Division of Radiology L-10, Cleveland Clinic Foundation, 9500 Euclid Ave. Cleveland, OH, 44195; (216) 444-2740. 10-1c

FELLOWSHIPS AT ALBANY MEDICAL CENTER—The newly-renovated and equipped Dept. of Radiology at the Albany Medical College and Center in Albany, NY, offers the following fellowship positions each yr: (1) Abdominal imaging—This fellowship encompasses all aspects of MRI, ultrasound, CT, and other advanced techniques in imaging the abdomen. Four state-of-the-art MRI and 4 CT scanners as well as 5 color Doppler ultrasound units are utilized daily. Contact James C. Peters, M.D. regarding this program. (2) Neuroradiology—This fellowship encompasses the full range of advanced neuro imaging including MRI, CT, angiography, and myelography. Contact William A. Wagle, M.D. (3) Angiography and interventional radiology—Three advanced angiographic suites are utilized daily for a full range of vascular and interventional procedures. Contact Mohammad S. Sarrafzadeh, M.D. All program directors listed above may be contacted at the Dept. of Radiology, A-113, Albany Medical Center, Albany, NY 12208; (518) 445-3277 or contact Matthew D. Rifkin, M.D., Chairman, Dept. of Radiology, A-113, at the above address. Albany Medical Center is an equal opportunity/affirmative action employer. 1-12c

FELLOWSHIP IN INTERVENTIONAL RADIOLOGY, UNIVERSITY OF SOUTHERN CALIFORNIA SCHOOL OF MEDICINE—Due to increased activity, the dept. of radiology has available 1-yr fellowship positions for the yrs 1992-93 and 1993-94 in interventional radiology beginning July 1, 1992. The interventional practice includes 3 contiguous hospitals. The primary teaching site of the university is the LAC+USC Medical Center, a 1,500-bed public facility. The adjacent Kenneth Norris Cancer Hospital is a 60-bed national cancer institute referral facility with an active interventional practice and the new USC University Hospital, a 275-bed private facility. The practice spans the breadth of interventional radiology with an exceptional experience in trauma and oncologic interventions. Interested candidates should contact Michael Katz, M.D., LAC+USC Medical Center, 1200 N. State St., Radiology, Rm. 3550, Los Angeles, CA 90033; (213) 226-7242. USC is an equal opportunity/affirmative action employer. 11-12c

PEDIATRIC RADIOLOGY, CHILDREN'S HOSPITAL, LOS ANGELES—Four fellowships annually in pediatric radiology with experience in general radiology, fluoroscopy, ultrasound, CT, MR, neuroradiology, angiography, interventional radiology, nuclear radiology and PET. Emphasis on clinical experience, education, and clinical research during training results in a comprehensive experience. One-yr fellowships are offered with an option of an additional year of specialized work. A specific fellowship in pediatric neuroradiology or special emphasis in angiography, interventional radiology is also available. Fellowship is ACGME accredited. CHLA is a 331-bed children's hospital servicing a community of 13 million. The dept. of radiology performs approximately 100,000 studies annually. All pediatric subspecialties are represented with centers in oncology, cardiopulmonary disease, neural sciences, and genetics established as part of the tertiary and quaternary mission of the hospital. Strong emphasis in teaching and training with 98 pediatric residents and over 100 fellows and Ph.D.s in hospital. Research at the CHLA Research Institute. Ten diagnostic, 1 radiation oncology and 1 Ph.D., MR physics faculty are full time in radiology. Dept. is completely equipped with state-of-the-art equipment including a 1.5-T magnet, 3 ultrasound units with color Doppler, and SPECT. For more information contact Beverly P. Wood, M.D., Dept. of Radiology, Children's Hospital Los Angeles, 4650 Sunset Blvd., MS# 81, Los Angeles, CA 90054-0700; (213) 669-5686, fax (213) 666-4655. 10-12c

FELLOWSHIPS - IMMEDIATE OPENINGS—The Dept. of Radiology, University of Rochester Medical Center, is offering fellowships in body imaging/interventional, neuroradiology, vascular/interventional radiology, and MR. Eligible applicants must be board-certified or eligible for certification in diagnostic radiology and should be eligible for licensing in the state of New York. Applicants should contact the program directors: MR and Body Imaging/Interventional, Deborah Rubens, M.D.; Neuroradiology, Leena Ketonen, M.D.; Vascular Interventional, Oscar Gutierrez M.D. Program directors can be contacted at the Dept. of Radiology, University of Rochester Medical Center, Box 648, 601 Elmwood Ave., Rochester, NY 14642; (716) 275-5200. EO/AA/M-F. 10-12c.

THE UNIVERSITY OF TEXAS M.D. ANDERSON CANCER CENTER, FELLOWSHIP IN BODY IMAGING AND VASCULAR INTERVENTIONAL RADIOLOGY—The Dept. of Diagnostic Radiology, University of Texas M.D. Anderson Cancer Center, is currently accepting applications for fellowships in body imaging and vascular interventional radiology for academic yrs. July 1993 - June 1994 and July 1994 - June 1995. The dept is equipped with state-of-the-art ultrasonography, computed tomography, magnetic resonance imaging, positron emission tomography, angiography, routing fluoroscopy, and mammography equipments. The fellows will have an opportunity to do clinical study with large number of clinical material seen at the institution and experimental research is available through Dunn Laboratory of Radiological Science. Candidates interested in these positions should write to Chuslip Charnsangavej, M.D., Professor and Deputy Chairman for Academic Affairs, Dept. of Diagnostic Radiology, Box 57, University of Texas M.D. Anderson Cancer Center, 1515 Holcombe Blvd., Houston TX 77030. 11-2c

INTERVENTIONAL MAMMOGRAPHY AND BREAST IMAGING FELLOWSHIP—The University of Arizona is offering a flexible 1-yr fellowship in interventional mammography and breast imaging beginning July 1993. The section performs more than 14,000 mammograms per/yr and over 500 breast interventional procedures, including percutaneous stereotaxic breast needle biopsy, preoperative localizations, and galactography. Equipment includes 7 state-of-the-art mammographic units and 5 stereotaxic devices. The fellowship will include 20% academic/protected research time and up to 4 months could be spent in other areas of body imaging (CT, ultrasound, or MRI). We have an active research program including clinical, basic science and technology assessment/outcome analysis research-related breast imaging. Other benefits include: relocation allowance, office space with computer, and funds to attend national meetings. No "night call" responsibilities. Salary \$38,500. Must be BC/BE. Will need Arizona license upon arrival. For further information please contact, Laurie L. Fajardo, M.D., Director, Mammography and Breast Imaging, University of Arizona, 1501 N. Campbell Ave., Tucson, AZ 85724. Application deadline, January 31, 1993. The University of Arizona is an equal opportunity/affirmative action employer. 10-1a

MR FELLOWSHIPS, IMMEDIATE OPENINGS—The Dept. of Radiology, University of Rochester Medical Center, MR fellowship offers a broad range of experience in both body and neuro MR. Associated imaging experience is available with CT. Research opportunities are available. Two 1.5-T G.E. Signa magnets with the latest software are in use and a third is being planned. Three CT units are in use. Eligible applicants must be board-certified or eligible for certification in diagnostic radiology and should be eligible for licensing in the state of New York. Contact Deborah Rubens, M.D., Dept. of Radiology, Box 648, University of Rochester Medical Center, Rochester, NY 14642; (716) 275-8365. EO/AA/M-F. 10-12c

FELLOWSHIP IN BODY IMAGING AND INTERVENTIONAL RADIOLOGY - USC SCHOOL OF MEDICINE—Commencing July 1, 1992, 1-yr fellowship positions for yrs 1992-1993 and 1993-1994 are available for board-certified radiologist to receive fellowship training in MR, CT, ultrasound, and interventional procedures guided by those modalities in the Dept. of Radiology, University of Southern California. This program offers superb training supervised by academically productive faculty in rich clinical setting. Excellent opportunities exist for supervised hands-on-training in MR, MR angiography, CT, CT-guided procedures, ultrasound, including color Doppler sonography and ultrasound-guided procedures. The dept. of radiology has state-of-the-art and prototype equipment in all modalities and offers excellent opportunity to achieve expertise in body imaging and related interventional techniques. Interested candidates should contact Philip W. Ralls, M.D., Chief of Body Imaging and Interventional Radiology, LAC/USC County Hospital, Box 631, 1200 North State St., Los Angeles, CA 90033; (213) 226-7207. USC is an equal opportunity/affirmative action employer. 11-12c

FELLOWSHIP IN ULTRASOUND, BODY CT AND MRI—July 1, 1994. 1-yr program featuring ultrasound, body CT, body MRI and noninvasive vascular diagnosis. For information and application contact William Zwiebel, M.D., Dept. of Radiology, University of Utah Hospital, Salt Lake City, UT 84132; (801) 581-7553. 4-2c

FELLOWSHIP IN VASCULAR/INTERVENTIONAL RADIOLOGY—The Yale University Dept. of Radiology has an unexpected opening for a third fellowship position starting July 1993. The section has an active clinical service performing a wide range of vascular and interventional procedures including: diagnostic angiography, angioplasty, stenting, atherectomy, infusion therapy, embolotherapy, IVC filter placement, and percutaneous renal, biliary, and abscess management. Additionally, there is an inpatient admitting service and clinic. The fellowship is for 1 yr. Please send CV and 3 letters of recommendation to Jeffrey Pollak, M.D., Section Chief, Dept. of Diagnostic Radiology, Yale University School of Medicine, 333 Cedar St., P.O. Box 3333, New Haven, CT 06501, (203) 785-4746, (203) 785-3024 fax. Yale University is an equal opportunity/affirmative action employer. Applications from women and minority group members are encouraged.

MRI FELLOWSHIPS—Fellowship positions in MRI are available from July 1994 and July 1995 at the Johns Hopkins Dept. of Radiology and Radiological Science. Flexible fellowship programs with clinical or research emphasis are available. The MRI division is equipped with 3 1.5-T GE scanners and 2 1.5-T Siemens scanners, both with cardiac imaging and spectroscopic capabilities. Over 9,000 exams are performed yearly. Over 2,000 of these exams are body MRI studies. In addition, a 4.7-T and an 8.5-T instrument with spectroscopic and imaging capabilities are available for research. The main interests of the section are in oncologic, cardiovascular, and musculoskeletal imaging. Rotating fellowships with CT and/or ultrasound or a straight MR fellowship are offered. For additional information and application, contact Elias A. Zerhouni, M.D., Director, Thoracic Imaging & MRI, Johns Hopkins Hospital, Baltimore, MD 21287; (410) 955-4062. 11-1cp

VASCULAR AND INTERVENTIONAL RADIOLOGY FELLOWSHIP—The University of Arkansas for Medical Sciences is offering a 1-yr fellowship in vascular and interventional radiology starting July 1, 1994. Training includes all aspects of angiography and vascular and non-vascular interventions. Ample clinical material is available at a university hospital, a large veteran's hospital and a children's hospital. Active vascular and non-vascular research programs are in place. Stipend and fringe benefits are competitive. Candidates must be board-certified or eligible in diagnostic radiology. Applications should include a current CV and 3 letters of reference. For further information, please contact either David R. McFarland, M.D., Chief, Section of Vascular and Interventional Radiology, Steven K. Teplick, M.D., Professor and Vice Chairman, or Ernest J. Ferris, M.D., Professor and Chairman, Dept. of Radiology/556, University of Arkansas for Medical Sciences, 4301 W. Markham, Little Rock, AR 72205; (501) 686-6910. 12-2c

PENN STATE UNIVERSITY, FELLOWSHIP IN CARDIOVASCULAR/INTERVENTIONAL RADIOLOGY—The Pennsylvania State University Dept. of Radiology offers 1- or 2-yr fellowships in cardiovascular/interventional radiology. Fellows will receive training in all aspects of diagnostic and interventional angiography (including neuro and pulmonary angiography), percutaneous and percutaneous/peroral GI interventions, GU interventions, venography, IVC filter placement, embolizations, foreign body retrievals, biopsy, drainage, and stenting procedures. Appointment at the instructor level is required, necessitating a Pennsylvania medical license, university hospital medical staff privileges, and ABR eligibility (at time of application) and certification (during first program yr). Independent original research is expected and is well supported. The animal research facility is excellent. A dedicated MR research facility with angiographic and spectroscopic capability exists. Both facilities are fully staffed by research associates and faculty and are equipped with state-of-the-art equipment. Eligibility: The fellowship is open to individuals who have completed an accredited residency program in radiology, can obtain a Pennsylvania medical license, and have fulfilled ABR requirements for board-certification/eligibility. Stipend: A generous and competitive salary and benefits package are offered. Academic, biophotographic, and secretarial support are also provided. Applications: Applicants should respond with a letter of interest and current CV. Please direct inquiries and requests for application forms to John F. Cardella, M.D., Assoc. Professor and Chief, Cardiovascular/Interventional Radiology Section, Penn State University/Hershey Medical Center, Box 850, Hershey, PA 17033. Penn State University is an affirmative action, equal opportunity employer; women and minorities are encouraged to apply. 11-1c

UNEXPECTED IMMEDIATE OPENING, FELLOWSHIP IN IMAGING/ANGIO-INTERVENTIONAL—There is an unexpected opening for a 1-yr fellowship program available immediately at the Lehigh Valley Hospital in Allentown, PA. The fellowship program offers training in CT (head and body), ultrasound, MR, angiography, and interventional radiography. LVH is a 514-bed acute-care, university-affiliated hospital. For further information contact Robert Kricun, M.D., Dept. of Radiology, Lehigh Valley Hospital, P.O. Box 689, Allentown, PA 18105-1556; (215) 402-8088.

FELLOWSHIP POSITIONS—The Dept. of Radiology, University of Utah School of Medicine. The University of Utah Dept. of Diagnostic Radiology is offering 2 1-yr fellowships to begin July 1993 in the following areas: (1) musculoskeletal radiology, (2) chest/breast imaging. Active services with outstanding clinical colleagues and up-to-date facilities. Academic time is built into the fellowships and research time is available on the magnets. Applicants must be board-eligible and have obtained a Utah medical license prior to commencing training. Please send CV specifying your area of interest to B. J. Manaster, M.D., Ph.D., Associate Professor of Radiology, Dept. of Radiology, 50 North Medical Dr., Salt Lake City, UT 84132. The University of Utah is an equal opportunity/affirmative action employer and encourages applications from members of minority groups and women. 12-3c

ACCREDITED FELLOWSHIPS IN PEDIATRIC RADIOLOGY AND PEDIATRIC NEURORADIOLOGY—The Dept. of Radiology, Children's Hospital and Harvard Medical School, Boston, MA, offers 1- or 2-yr accredited (Residency Review Committee for Radiology of ACGME) fellowships in pediatric radiology beginning July 1, 1994. A 1-yr pediatric neuroradiology fellowship program is also offered. Children's Hospital is a 350-bed institution. The dept. performs over 102,000 radiological exams/annually in one of the largest children's hospitals in North America. The dept. has 16 faculty pediatric radiologists, 2 research faculty, 1 physicist, 9 pediatric radiology fellows, 2 neuroradiology fellows, and many resident trainees. Six pediatric radiology and 1 pediatric neuroradiology fellowship positions are available annually. Training includes all aspects of pediatric imaging: neonatal radiology; neuroimaging; musculoskeletal radiology; cardiovascular and thoracic imaging; abdominal imaging; oncologic imaging; ultrasonography; nuclear medicine; computed tomography; MRI; and vascular/interventional procedures. The dept. has an extremely active clinical service with state-of-the-art equipment as follows: digital fluoroscopy; computed radiography; Acuson ultrasound units with Doppler and color-flow Doppler capabilities; planar and SPECT gamma cameras; GE 9800 Highlight Advantage CT scanner; 1.5-T GE MRI with spectroscopy and MR angiography; angiocardiology suites with digital vascular imaging; and vascular/interventional suite with digital vascular imaging. The dept. provides extensive academic support; the Stem Memorial Radiology Library and departmental librarian are valuable resources. The fellowship provides a broad clinical experience in pediatric radiology as well as numerous opportunities to participate in both clinical and basic research. There are opportunities for collaborative research efforts at Children's Hospital, other Harvard teaching hospitals, and Harvard Medical School. Candidates must be board-certified or board-qualified in diagnostic radiology and must obtain a Massachusetts Medical License. Salary and fringe benefits are highly competitive. Applications are due no later than February 1993 with interviews scheduled during the fall and winter of 1992-93; there are numerous career opportunities in pediatric radiology and pediatric neuroradiology in both academic and private practice settings. To receive more information about the fellowships at Children's Hospital or careers in pediatric radiology, please contact Donald R. Kirks, M.D., Chairman, Dept. of Radiology, Radiologist-in-Chief, Children's Hospital, 300 Longwood Ave., Boston, MA 02115; (617) 735-6291. Children's Hospital and Harvard Medical School are affirmative action/equal opportunity employers. 12-3c

FELLOWSHIP IN NEURORADIOLOGY—Mayo Clinic Dept. of Radiology, Rochester, MN, has an unexpected opening for an accredited 1-yr fellowship in neuroradiology to begin July 1993. The Mayo Clinic neuroradiology practice is active in all aspects of diagnostic and interventional neuroradiology. Please send a CV and a letter of inquiry to Dr. Patrick Luetmer, Neuroradiology Fellowship Coordinator, Dept. of Diagnostic Radiology, Mayo Clinic, 200 First St., S.W., Rochester, MN 55905; (507) 284-5114. The Mayo Clinic is an equal opportunity employer. 11-12a

BODY IMAGING FELLOWSHIP (ULTRASOUND, BODY CT, AND MRI), TO BEGIN JULY 1993—The Dept. of Radiology at Albert Einstein Medical Center Hospital in Philadelphia, PA, offers a 1-yr body imaging fellowship. Albert Einstein Medical Center is a 650-bed, advanced tertiary-care teaching hospital. The fellowship emphasizes diagnostic ultrasound with rotations in body magnetic resonance imaging and computed body tomography. The program is flexible and negotiable. Examinations in all areas of sonography are performed and include obstetrics and gynecology, vascular/Doppler, abdominal, prostate, pediatrics, breast and small parts. There is state-of-the-art equipment in all areas of the dept. Fellows participate in procedures guided by ultrasound and computed tomography and have ample opportunity to participate in conference presentations and research projects, many of which culminate in publication. Inquiries should be addressed to Henrietta Kotlus Rosenberg, M.D., Chairman, Dept. of Radiology, Albert Einstein Medical Center, 5501 Old York Rd., Philadelphia, PA 19141. 12-2c

VASCULAR/INTERVENTIONAL RADIOLOGY FELLOWSHIP—Temple University Hospital and School of Medicine has available a 1 yr fellowship beginning July 1, 1993. The candidate will have exposure to all areas of vascular and interventional radiology including noninvasive techniques and MRI/A. Approximately 1,100 procedures are performed annually including: vascular/non-vascular stents, TIPSS, transcatheter and percutaneous embolotherapy, extensive endourologic and biliary interventional procedures. Applicants should contact David S. Ball, D.O., Chief, Section of Vascular/Interventional Radiology, Dept. of Diagnostic Imaging, Temple University Hospital, 3401 N. Broad St., Philadelphia, PA 19140. Temple University Hospital and School of Medicine is an affirmative action/equal opportunity employer. 12a

MAGNETIC RESONANCE IMAGING (COMBINED NEURO, MUSCULOSKELETAL AND BODY) FELLOWSHIP, THOMAS JEFFERSON UNIVERSITY HOSPITAL—The Dept. of Radiology at Thomas Jefferson University Hospital has created 2 new openings for 1-yr fellows beginning July 1, 1993. Responsibilities will be split between active neuroradiology and body/musculoskeletal MRI sections. Equipment includes 4 1.5-T GE Signa systems with state-of-the-art and advanced prototype hardware and software. Ample opportunities for clinical responsibility are provided. Interested candidates should contact Donald G. Mitchell, M.D., Director of MRI, Dept. of Radiology, 1096 Main Building, Thomas Jefferson University Hospital, Philadelphia, PA 19107; (215) 955-4809. Jefferson is an equal opportunity/affirmative action employer.

FELLOWSHIP IN IMAGING/ANGIO-INTERVENTIONAL—A 1-yr fellowship program at Lehigh Valley Hospital in Allentown, PA, is available. LVH is a 514-bed acute care university-affiliated hospital. The fellowship program offers training in CT (head and body), ultrasound, MR, angiography, and interventional radiology. For further information contact Robert Kricun, M.D., Dept. of Radiology, Lehigh Valley Hospital, P.O. Box 689, Allentown, PA 18105-1556. 10-12c

VISITING MRI FELLOWSHIP IN SAN FRANCISCO—Weekly, clinical hands-on fellowship in musculoskeletal-body and/or neuro MRI. Limited to 2 participants. Interactive readout of scans (30-40 per day) and case discussions with senior faculty. Participation in prescan decision making. Film and video teaching files. Dates by arrangement. Contact Christian H. Neumann, M.D., Ph.D., (415) 563-3133, or write, San Francisco Magnetic Resonance Center, UCSF, Laurel Heights Campus, 3333 California St., #105 San Francisco, CA 94118. 12c

FELLOWSHIP IN PEDIATRIC IMAGING, DUKE UNIVERSITY MEDICAL CENTER—The Dept. of Radiology at Duke University Medical Center offers a 1- or 2-yr fellowship in pediatric imaging. This fellowship is designed to prepare the trainee for a career in pediatric radiology in a university, community or children's hospital setting. The fellow will work closely with pediatric radiologists and academic subspecialists in radiology. Clinical exposure includes pediatric imaging in neuroradiology, musculoskeletal radiology, cardiac radiology, chest radiology, GI radiology, GU radiology, and oncologic radiology. Imaging modalities include conventional and digital radiography, ultrasonography, nuclear medicine, computed tomography, magnetic resonance imaging, angiography, and interventional techniques. The fellow will participate in ongoing clinical research projects. Elective time during the second fellowship yr would permit the fellow to participate in basic and clinical research and to gain additional subspecialty experience. For further information, contact Carl E. Ravin, M.D., Professor and Chairman, Dept. of Radiology, Duke University Medical Center, Box 3808, Durham, NC 27710, Herman Grossman, M.D., Professor of Radiology and Pediatrics, Chief, Pediatric Imaging, Dept. of Radiology, Duke University Med. Center, Box 3834, Durham, NC 27710. Duke University is an affirmative action equal opportunity employer. 12-2c

FELLOWSHIP IN BODY MRI, CT, AND ULTRASOUND—The Dept. of Radiology at Hahnemann University Hospital, Philadelphia, PA, offers a 1-yr fellowship in body imaging. Three positions are available for July 1994 to June 1995. The fellowship will provide state-of-the-art training on ultrasound/CT/MRI. Equipment includes: Acuson and ATL ultrasound with color Doppler, 2 GE 9800 and a Signa 1.5-T MRI. Applicants must have completed an approved residency in diagnostic radiology and be board-eligible/certified. For inquiries, please contact Thomas Niedbala, M.D., Dept. of Diagnostic Radiology, Hahnemann University Hospital, Broad and Vine Streets, Philadelphia, PA 19102; (215) 762-8742. An equal opportunity employer. 12-2cp

ONE-YR FELLOWSHIP IN ANGIOGRAPHY/INTERVENTIONAL RADIOLOGY—The Dept. of Radiology, The George Washington University Medical Center, Washington, D.C., is accepting applications for a 1-yr fellowship in angiography/interventional radiology beginning July 1, 1994. The section consists of 2 adjoining state-of-the-art angio suites sharing a large common control room. The section is responsible for all non-neuro and non-cardiac diagnostic angiography as well as all non-vascular image guided interventions, utilizing ultrasound, CT or fluoro. The section is clinically oriented and actively involved in direct patient care. A full range of diagnostic and therapeutic procedures are performed. Cross-training in vascular ultrasound and vascular MRI are possible. Approximately 800 cases/yr. Applicants must be graduates of an approved US medical school or its equivalent, must have completed an approved residency in diagnostic radiology, be eligible for ABR certification, and be eligible for medical licensure in the District of Columbia. Please send inquiries with CV to Edward M. Druy, M.D., Dept. of Radiology, The George Washington University Medical Center, 901 23rd St., N.W., Washington, D.C., 20037. The George Washington University is an EEO/affirmative action employer. 12c

NEURORADIOLOGY FELLOWSHIP—Two yrs beginning July 1, 1993. Exposure to all aspects of clinical/academic neuroradiology including CT, MRI, interventional procedures, vascular ultrasonography and pediatric neuroradiology. Participation in research and teaching. Send cover letter/CV to Te-Hua Liu, M.D., Director, Neuroradiology Section, Dept. of Diagnostic Imaging, Temple University Hospital, 3401 N. Broad St., Philadelphia, PA 19140. Temple University is an affirmative action/equal opportunity employer. 12c

PEDIATRIC RADIOLOGY AND MRI RESEARCH FELLOWSHIP—At the University of California, San Francisco, starting July 1, 1993, a unique opportunity for a 1- or 2-yr experience focused on clinical pediatric imaging. A significant portion of effort can also be devoted to related research as a sponsored fellow. UCSF is an equal opportunity/affirmative action employer. Minority groups, women and handicapped individuals are encouraged to apply. Interested applicants should write or call Robert C. Brasch, M.D., Dept. of Radiology, UCSF, San Francisco, CA 94143-0628; (415) 476-2275. 12c

Tutorials/Courses

CARIBBEAN CRUISE-NEURO IMAGING/MRI AT SEA—January 10-17, 1993. Faculty: Hervey Segall, M.D. CME I application. Medical Seminar International, Inc., 18981 Ventura Blvd. Ste. 303, Tarzana, CA 91356; (818) 774-9077, fax (818) 774-0244. 9-12d

DIAGNOSTIC IMAGING IN ARUBA—The Dept. of Radiology, Cornell University Medical College, and The New York Hospital will present the 18th annual postgraduate course, Diagnostic Imaging, January 31-February 5, 1993, at the Hyatt Regency Hotel in Aruba. Category I credit: 30 hrs. Fee: Physicians, \$495; residents, fellows and technologists \$295. Information: Ms. Julia Anne Mala, Radiology, Cornell University Medical College, 1300 York Ave., New York, NY 10021; (212) 746-2522. 9-12d

CARIBBEAN CRUISE-BREAST IMAGING AT SEA—January 17-24, 1993. Presented by a renowned faculty member: Marc J. Homer, M.D. CME I application. Medical Seminars International, Inc., 18981 Ventura Blvd., Ste. 303, Tarzana, CA 91356; (818) 774-9077, fax (818) 774-0244. 9d

CARIBBEAN CRUISE-MRI AT SEA—January 24-31, 1993. Faculty: Barry S. Goldberg, M.D. CME I application. Medical Seminars International, Inc., 18981 Ventura Blvd., Ste. 303, Tarzana, CA 91356; (818) 774-9077, fax (818) 774-0244. 9-12d

Announcement 1993 AJR Classified Advertising Rates

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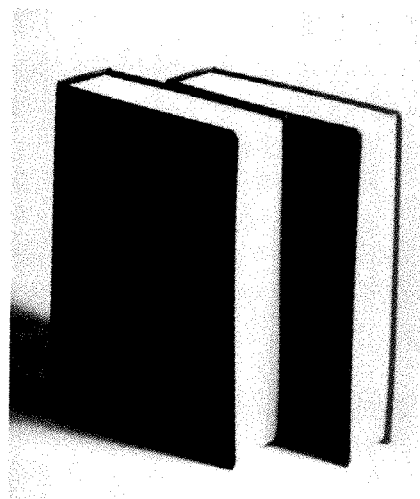
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